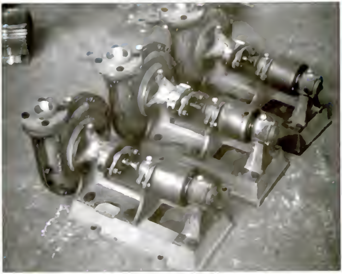
Water Reports 14

ISSN 1020-1203



IRRIGATION TECHNOLOGY TRANSFER IN SUPPORT OF FOOD SECURITY

Food and Agriculture Organization of the United Nations

WORLD BANK
IPTRID

ISSN 1020-1203

Water Reports **14**

IRRIGATION TECHNOLOGY TRANSFER IN SUPPORT OF FOOD SECURITY

Proceedings of a subregional workshop
Harare, Zimbabwe
14-17 April 1997

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1997

The views expressed in this paper are those of the authors. The mention of specific companies or of their products or brand names does not imply any endorsement by, and the views expressed do not necessarily reflect the views of, the Food and Agriculture Organization of the United Nations or the International Program for Technology Research in Irrigation and Drainage.

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations or the International Program for Technology Research in Irrigation and Drainage concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

M-56
ISBN 92-5-104072-9

Preface

The World Food Summit (November 1996) adopted a Global Plan of Action to achieve the objective of food security. The Plan envisaged an effort to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half their present level no later than 2015. The Plan of Action consists of a set of specific recommendations to be implemented by governments in partnership with all actors of civil society, and with the support of international institutions, which among others, includes:

- *developing appropriate national and regional policies and plans for water and watersheds, and water management techniques; and*
- *promoting economically- and environmentally-sound irrigation management, in particular for small-scale irrigation, and sustainable intensification of rainfed agriculture.*

Food security is a complex issue. Many factors influence a nation's food security status. However, for many developing countries, increasing national agricultural production will be a major contributing factor to food security. Water, among others, plays a critical role in increasing agricultural production.

The Special Programme for Food Security (SPFS) was launched by FAO in 1994 to assist low-income-food-deficit countries to boost food production in order to meet rapidly growing demands and help eradicate food insecurity. The programme is designed for a phased implementation. The phases include: (i) exploratory mission; (ii) formulation of the national programme; (iii) implementation of the pilot phase; and (iv) expansion phase. The Programme is being implemented in some 29 countries and in a majority of them the pilot phase has begun. The pilot phase consists of four elements: water control, intensification, diversification and analysis of constraints to food security.

In order to ensure that the SPFS and other efforts successfully achieve food security there is an urgent need to create an enabling environment at national and local levels. This environment will allow the management of natural resources, improve access to modern and cost-effective technologies and mobilize human and financial resources for accelerated agricultural development.

A number of studies carried out on irrigation development in sub-Saharan Africa during the last two decades indicated that, among others, lack of access to affordable and water-saving irrigation technologies, particularly by small-scale farmers, was a major constraint to irrigation development. This prompted FAO and the International Program for Technology Research in Irrigation and Drainage (IPTRID) jointly to launch a series of missions on irrigation technology transfer and adoption in selected countries in East and Southern Africa. The missions confirmed the hypotheses that: (a) there is under-utilized potential of rainfed lands which are close to water sources and could therefore be irrigated. If low-cost pumping is made available it would increase local production significantly; (b) the involvement of the

private sector in the manufacture, supply and servicing of equipment for small-scale irrigation is essential to make equipment easily accessible to farmers; and (c) irrigation equipment in East and Southern African countries is much more expensive than in Asian countries, in general, and particularly in India and China (up to five times). Promotion of irrigation technology transfer and adoption is, therefore, one of the key elements to achieve food security in developing nations.

This Subregional Workshop on Irrigation Technology Transfer in Support of Food Security was organized to share the findings of the missions and other relevant information related to the subject with the stakeholders of small-scale irrigation development in East and Southern African countries and formulate a plan of action to promote irrigation technology transfer and adoption in support of small-scale irrigation development and thereby contribute to food security. The Workshop was funded by FAO, IPTRID and the Global Water Partnership (GWP). It was attended by some sixty participants including government-nominated experts, non-governmental organizations (NGOs), irrigation equipment manufacturers and suppliers (private sector), resource persons, representatives of specialized institutions, and multi- and bilateral agencies. The Workshop discussed the issues and opportunities in irrigation technology transfer and adoption and recommended actions to be undertaken by national governments in collaboration with NGOs, the private sector and relevant international institutions.

The Proceedings contain two main parts. Part I presents the recommendations of the Workshop adopted by the participants at the plenary session and the recommendations of the Working Groups. Part II contains the technical papers presented by resource persons and representatives of the irrigation equipment manufacturing and supplying sector. The papers have been edited and condensed, where necessary, to keep within limits specified for the publication. The annexes provide related information such as a summary report of the Workshop, opening and closing addresses and the programme.

Contents

List of acronyms

ADA	Agricultural Development Agency
ADP	Agricultural Development Projects
AGRITEX	Agricultural Technical and Extension Services
ApproTEC	Appropriate Technologies for Enterprise Creation
ATI	Appropriate Technology International
BIS	Bureau of Indian Standards
CARE	International non-governmenal organization
CARMATEC	Irrigation Equipment Testing Programme of the University of Tanzania, Arusha)
CAMPFIRE	Communal Areas Management Programme for Indigenous Resources
CFAF	West African franc
CIF	Cost insurance and freight
CROPWAT	A computer program to calculate crop water requirenments
CSIR	Agricultural Research Council
DOI	Department of Irrigation
ESA	External Support Agency
FAO	Food and Agriculture Organization of the United Nations
FO	Farmers' organization
FOB	Freight on board
FTC	Full tank level
IAR	Institute for Agricultural Research
ICID	International Commission for Irrigation and Drainage
ICFU	Indigenous Commercial Farmers' Union
IDB	Irrigation Drainage Branch
IDE	International Development Enterprises
IEC	International Electro-Technical Commission
IFAD	International Fund for Agricultural Development
IIMI	International Irrigation Management Institute
IPI	Institute for Promotion of Innovations
IPTRID	International Programme for Technology Research on Irrigation and Drainage
ISO	International Organization for Standardization
ITDG	Intermediate Technology Development Group

LDPE	Low density polyethylene pipe
LIFDC	Low-income food deficit countries
LLDPE	Liner low density polyethylene pipe
MAFF	Ministry of Agriculture, Food and Fisheries
MBS	Malawi Bureau of Standards
mcft	million cubic feet
MIRTDC	Malawi Industrial Research and Technology Development Centre
MOA	Ministry of Agriculture
MWL	Maximum water level
NABL	A national level regulating body for equipment standards
NFIF	National farm irrigation fund
NGO	Non-governmental organization
NIDP	National Irrigation Development Plan
ODA	Overseas Development Administration
PVC	Poly vinyl chloride
REST	Relief Society for Tigray
RITES	Indian standards agency
SABI	South African Irrigation Institute
SAFR	Subregional Officer for Southern and East Africa
SAP	Structural Adjustment Programme
SADC	Southern African Development Community
SIEMA	Southern India Engineering Manufacturers' Association
SISDO	Smallholder Irrigation Scheme Development Organization
SITARC	Small Industries Testing and Research Centre
SPFS	Special Programme for Food Security
TBL	Tank bund level
TCDC	Technical Cooperation among Developing Countries
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
VAT	Value added tax
WRC	Water Resources Commission
WUA	Water Users' Association
ZITC	Zimbabwe Irrigation Technology Centre
ZSA	Zimbabwe Standards Association
ZFU	Zimbabwe Farmers' Union

Acknowledgements

Gratitude is expressed to the Government of Zimbabwe for hosting the Workshop and to the Honourable Minster of Agriculture, Dr D. Norman, and the Honourable Minster of Lands and Water Resources, Dr K. M. Kangai, for their opening and closing speeches respectively.

The technical papers contributed by the resources persons and active participation of government-nominated experts, NGOs, equipment manufacturers and suppliers and representatives of multilateral and bilateral organizations are gratefully acknowledged.

Special thanks are due to the Global Water Partnership for their generous financial support and to the International Programme for Technology Research in Irrigation and Drainage (IPTRID) for collaboration and support for the pre-Workshop missions and for preparation of documents for the Workshop.

The encouragement and support of Ms. Sekitoleko, Subregional Representative, and staff of the FAO Subregional Office for Southern and East Africa (SAFR), and the continuing support of Mr Hans Wolter, Chief, Water Resources, Development and Management Service (AGLW), Land and Water Development Division, are greatly appreciated.

Special thanks are due to Messrs Arumugam Kandiah and Reto Florin, Senior Officers, AGLW, and Mr Randall Purcell, Program Manager, IPTRID, for the overall planning and coordination of the Workshop; Messrs Andreas Savva and Andries Bosma, SAFR, for technical and organizational support to the Workshop; and Mr. Neil Paul for editing the report and the technical papers.

PART I

Workshop recommendations

We, the participants of the workshop on Irrigation Technology Transfer, held in Harare, Zimbabwe, 14 to 17 April 1997, recommend to our respective governments and institutions to work together in:

(1) defining and implementing comprehensive strategies for smallholder irrigation development;

(2) launching national action oriented programmes for the promotion of efficient irrigation technologies;

(3) launching action oriented programmes for the development of local water resources;

(4) launching programmes for national capacity building in irrigation design and use.

Comprehensive strategy

Evidence from Asian countries shows that smallholder irrigation can make a significant contribution towards poverty alleviation, rural employment and food security. In the light of this evidence, it is recommended that governments in the sub-Saharan region give high priority to smallholder irrigation. There is need to formulate a comprehensive strategy to promote small-scale irrigation, including the accessibility of appropriate and affordable technology.

Such a strategy should include the following components:

- Review existing regulations and policies that influence small-scale irrigation.
- Review administrative regulations and restrictions on marketing and trade of irrigation equipment.
- Review import duty and tax structures, including import duties on raw materials, machine tools and irrigation equipment.
- Define the role of government institutions, private sector and non-governmental organizations (NGOs) in promoting the adoption of improved irrigation technologies by small farmers. The private sector and NGOs should be encouraged to participate. However, it is recognized that government should play an active part in the identification and development of appropriate technologies and in the wider issues of rural infrastructural development.
- Develop a legal framework to ensure land and water rights of smallholders.
- Develop policies and guidelines so that watersheds are considered as basic units for planning and development of small-scale irrigation. Encourage mechanisms that will permit balancing of benefits and costs of water development in a river basin.
- Widening the knowledge base with regard to:
    - **Farmer knowledge**: Assessment of technology needs, on-field and on-station demonstrations of technology, deployment of irrigation technology advisers.
    - **Design of systems and equipment:** Training technicians in irrigation equipment and system design to work in both private and public sectors.
    - **Design norms:** Review existing design norms/criteria and modify with the aim to simplify and reduce costs of small-scale systems. Ensure that schemes are designed for operation and management by the users.

- **Quality:** Encourage voluntary submission of products for certification and verification of design characteristics.
- **Marketing:** Promote the concepts of rural marketing through private sector and NGO initiatives.

- Promote local manufacturing of equipment, complemented by imports. Encourage local manufacturers, joint ventures and foreign investors through:
  - Tax incentives
  - Provision or guarantee of credit
  - Provision of services - warehousing, building sites and connection to services
  - Simplify administrative procedures for licensing
  - Regulations for the repatriation of profits
- Encourage private investment in irrigation through provision of credit and financial incentives targeted to smallholder irrigation.
- Improvement of rural infrastructure, specifically relating to roads and energy supply.

Action programmes

The following-action programmes are recommended to national governments, NGOs, the private sector and the donor community, for coordinated implementation.

Adaptation and Dissemination of Small-scale Irrigation Technologies

Experiences in Africa and abroad (South Asia) have shown that low-cost technologies could be easily disseminated and would rapidly boost the development of small-scale irrigation from aquifers and surface water resources. Among these techniques are:

- Manual drilling technologies such as hand augured wells for shallow aquifers
- Mechanical drilling in deeper aquifers
- Human powered water lifting devices, such as treadle pumps and others
- Gasoline, kerosene , diesel and electric powered pumps
- On-farm irrigation distribution systems for smallholder groups

National programmes aimed at promoting such technologies should be jointly undertaken by the public and private sectors and NGOs. These programmes should include awareness building and participation of beneficiaries (including women), training of beneficiaries, field testing, when necessary, and commercialization of equipment.

Programme on communal small-scale irrigation, water development and conservation

This programme is aimed at improving farmers' access to water for small-scale irrigation, through the construction of micro-dams and water diversion structures, using cost-effective technologies. The programme also entails farmer participation in all phases of irrigation development, such as construction of dams and diversion structures, wells and other water sources, on-farm water management and soil and water conservation activities within the watershed.

To achieve the above goals, the programme will develop appropriate guides on planning, site selection, design, construction of cost-effective structures, operation and maintenance of such structures as well as on-farm water management. The programme also includes activities designed to promote local manufacture of appropriate equipment for the construction of small irrigation works, arrive at optimal combinations of mechanical and labour inputs in small-scale irrigation development and other actions that will ensure technical, economic and social viability of small-scale irrigation schemes. More specifically, the programme includes the following components for implementation:

- Developing a manual on simple design and standards for micro-dam and river diversion structures including:
  - site selection;
  - design parameters;
  - construction methods and management;
  - operation and maintenance; and
  - on-farm water management.
- Promoting local manufacture of equipment for small-scale irrigation construction, such as improved manual, animal drawn and tractor powered compactors, transport carts, scrapers, scoops; etc.
- Assessing performance and status of existing small-scale irrigation schemes, water points, dams and traditional schemes, and recommending action to improve their performance, rehabilitate infrastructure and restructure the existing management system.
- Studies on the relative roles of labour and machinery in small-scale irrigation construction in the context of cost reduction, employment generation, availability of labour and related socio-economic factors.
- Pilot projects to evaluate options of incentives and other mechanisms that ensure equity of benefits to upsteam and downstream communities.

Programme to strengthen national capacity in small-scale irrigation development

The programme aims at national capacity building in small-scale irrigation development which includes the following components:

- A programme directed towards strengthening the capacity of the private sector, the public sector and NGOs. This programme will cover the areas of planning, designing, construction and water management related to manual and mechanized drilling, water lifting devices and on-farm irrigation scheme development. The programme will have a strong element of on-the-job training and will also incorporate the strengthening of the irrigation component of agricultural engineering programmes of national universities, through exchanges, short courses and research grants.
- Provision of technical, in-service training to technicians and extension agents on construction, maintenance, operation of micro-dams and river diversions, well construction, on-farm water management and watershed management.
- Organization of specialized training for engineers, graduates, national consultants and contractors in planning, design, site selection and construction of micro-dams and river diversion structures through Technical Cooperation among Developing Countries

(TCDC) and other appropriate mechanisms. Such training could be conducted in the countries of trainees and/or in countries where the expertise and experience exist.

RECOMMENDATIONS OF THE WORKING GROUPS

WORKING GROUP I

Theme: Low cost technology for individual farmers or small groups of farmers. *(What can be done and by whom, to increase the availability of low-cost irrigation equipment to smallholder farmers)*

Chairperson:	A.E. Daka, Zambia
Facilitators:	C.P. Mzembe, Malawi A.P. Savva, FAO, SAFR R.Purcell, IPTRID F.Gadelle, IPTRID
Resource Person:	E. Perry, USA
Members of the Group:	P.C. Moffat, Ministry of Agriculture, Botswana M. Woldeyohannes, Ministry of Agriculture, Eritrea T. Mekonnen, ESRDF, Ethiopia M. Sonou, FAO, RAF M.K. Gakundi, SISDO, Kenya L.A. Arao, consultant, Kenya H. Blank, IIMI, Kenya H.K. Mwathe, Ministry of Agriculture, Kenya A.T. Khonje, Department of Irrigation, Malawi M. Mangueze, Dept. of Agr. Hydraulics, Mozambique R. Mtileni, South Africa G.M. Kalinga, Ministry of Agriculture, Tanzania J.M. Ogwang, Ministry of Agriculture, Uganda S. Masarira, Ministry of Agriculture, Zimbabwe S. Hungwe, ZFU, Zimbabwe

General set of recommendations

- Need to enhance access to water resources for farmers through programmes of water resources and irrigation development.
- Need for testing and marketing devices and irrigation systems.
- Need to improve mechanisms for credit provision.
- Need to develop appropriate legal framework to ensure land security of smallholders.
- Need to enhance extension and technical support services in irrigation.
- Need to enhance research and development and information exchange within the sub-region and among extension and research services.

- Need to develop marketing support which should include agro-processing.
- Within this general framework, there is a need for national capacity building which should emphasize on-the-job training; as such it should focus more on the private sector and NGOs.
- Need to enhance market information systems for farmers.
- Need for irrigation programmes at national universities and colleges.
- Within this framework of recommendations, responsibility for services should gradually be shifted from government to the private sector and NGOs. This responsibility applies especially to equipment provision, design construction and training in operation and maintenance (O&M). There is a need to strengthen the governments' capacity in other areas, such as planning and supervision of design and construction, through public investment programmes. Also, within this framework, there is a need to pay more attention to the role of women in irrigation and to consider the impact of irrigation development on the environment.

Suggested innovative programmes

1. Based on experiences in Africa and elsewhere, introduction of joint private sector and government programmes for proven manual drilling technologies, well development and water lifting, focusing on field testing (where necessary), training and commercialization. Programmes for awareness building among, and participation of, beneficiaries will also be included. The programme should be limited to shallow aquifers and surface water.
2. A similar programme, also focusing on the smallholder, to promote uptake of low-cost mechanized well drilling, pumping and on-farm irrigation systems.
3. A review of existing funding and credit mechanisms for low-cost technology, small-scale irrigation development, both private and public, along with an examination of how success elsewhere might be transferred to the countries of the region.
4. Programmes to strengthen private and public national capacity in planning, design, construction, O&M and monitoring, starting with a needs assessment and a strong on-the-job training component.
5. As part of an on-going development effort, a pilot project to evaluate alternative extension service models emphasizing farmer participation in deciding what kind of extension they need, where and how it can be obtained.
6. Enhance the capacity of national committees of ICID to network, exchange experiences and conduct research in smallholder irrigation.
7. Programmes to develop market information systems as part of extension services, drawing on examples of Zimbabwe, Mali and other countries, where these are in place and effective.
8. Strengthening the irrigation component of existing agricultural engineering programmes through short courses, exchanges and "research" grants.

WORKING GROUP II

Theme: Local manufacture, supply and technical services and demonstration of irrigation technologies

Chairperson :	R.J. Chitsiko, Zimbabwe
Facilitators :	H. Wolter, FAO, Rome G. Cornish, H.R. Wallingford, UK
Resource Person:	M. de Lange, consultant, South Africa
Members of the Group:	W. Zhou, manufacturer, China C. R. Shanmughasundaram, manufacturer, India M. Fisher, Approtec, Kenya R.N. Patel, manufacturer, Malawi L.Hugo, Ministry of Agriculture, Water and Rural Development, Namibia F. Koegelenberg, manufacturer, South Africa J.B. Kalule-Sewali, Ministry of Agriculture, Uganda L. Egan, IDE, USA E. Chidenga, Agritex, Ministry of Agriculture, Zimbabwe A. Sezanje, University of Zimbabwe, Zimbabwe F. Taka, Ministry of Agriculture, Zimbabwe C. Kamuti, Ministry of Agriculture, Zimbabwe N. Moyo, ICFU, Zimbabwe

Evidence from Southern and Eastern African countries shows that smallholder irrigation can make a contribution towards poverty alleviation, food security and the national economy. Consequently, it is recommended that governments in this region reconsider the importance of smallholder irrigation. There is need to formulate a comprehensive strategy to promote small-scale irrigation, including the accessibility of appropriate and affordable technology. Such a strategy should include the following components:

- Review existing regulations and policies that influence small-scale irrigation.
- Define the role of government institutions, private sector and NGOs.
- Assessment of technology needs among smallholder farmers.
- Widening the knowledge base with regard to:
  - Use of technologies
  - Design of systems
  - Design and manufacturing of equipment
  - Marketing
- Promote local manufacturing of equipment complemented by imports when necessary.
- Improvement of local infrastructure, specifically relating to roads and energy supply.

International organizations and donors can assist governments of the sub-region in the formulation of policies and necessary action with respect to the following issues:

Issues and suggested action

Regulations and policies affecting small-scale irrigation

- Review administrative regulations and restrictions on marketing and trading of irrigation equipment.
- Review import duty and tax structures, including import duties on raw materials, machine tools and irrigation equipment, reduced VAT and other purchase taxes.
- Simplify administrative procedures for funding of joint ventures.
- Review credit facilities available to smallholders.

Role of government institutions, private sector and NGOs

Wherever possible, the private sector and NGOs should be encouraged to lead in promoting the adoption of improved irrigation technologies by small farmers. This involvement of the private sector and NGOs will also include provision of services for the repair and maintenance of equipment and agricultural input supply. However, it is recognized that governments must play an active part in the identification and development of appropriate technologies and in the wider issues of rural infrastructural development.

Technology needs assessment

In view of the initial small size of the market, governments will have to lead in assessing the needs and opportunities for improved smallholder irrigation technologies.

Widening the knowledge base

Improving farmer knowledge

- Mobile, on-farm and permanent demonstrations with government and private sector cooperation.
- Train and dcploy irrigation advisers.

Knowledge for design

- Training technicians in irrigation equipment and system design to work in both private and public sectors.
- Review existing design norms/criteria and modify with the aim to simplify and reduce costs of small-scale systems.
- Ensure that schemes are designed for operation and management by the users.

Knowledge to market products

- Promote the concepts of rural marketing through private sector and NGO initiatives.

Financial incentives

Encourage local manufacturers, joint venture and foreign investors through:

- tax incentives;
- provision of services - warehousing, building sites and connection of services;

- guaranteed repatriation of profits;
- simplified administrative procedures.

Standards and certification

Encourage voluntary submission of products for certification and verification of design characteristics.

Rural infrastructure

Improve of rural infrastructure and in particular roads, as a prerequisite to wide scale adoption of irrigation technologies by small farmers. Equally, access to affordable and reliable energy sources is essential for mechanized technologies.

WORKING GROUP III

Theme: **Appropriate technologies for communal water development and water conservation** *(What can be done to improve access to water and to promote cost-efficient water development technologies)*

Chairperson: N. Tafesse, Ethiopia

Facilitators: A. Kandiah, FAO Rome
R. Florin, FAO Rome

Resource Person: R.K. Sivanappan, India

Members of the Group: A. Wolde Amanuel, Ministry of Agriculture, Ethiopia
H. Gesesa, NGO, Ethiopia
A. Wakie, ESRDF, Ethiopia
C.J. Lovel, ODA
R.L. Daluti, Ministry of Agriculture, Tanzania
H.M. Mwanza, MAFF, Zambia
J. Phakati, KATC, Zambia
R. Siziba, Ministry of Agriculture, Zimbabwe
P.R. Ndlovu, Ministry of Agriculture, Zimbabwe
A. Mondiwa, CARE, Zimbabwe
J. Kwadamba, Farming News, Zimbabwe

In areas where rainfall is unreliable, or where there are no perennial sources of surface water or shallow groundwater, there is need for harvesting excess rainfall, surface runoff and stream flow. This harvesting can be done by constructing various water harvesting structures and by implementing water conservation measures to promote irrigation. Even in areas where there are perennial water sources, there is need to develop small water storage, water diversion and water pumping methods to promote irrigated agriculture. To make such small-scale water projects sustainable, there is need for a simultaneous programme to undertake watershed management and protection. Such programmes should be aimed at controlling erosion and runoff, increase groundwater recharge and preserve the watershed eco-system. All these activities are beyond the capacity or means of individual farmers, but should be

undertaken by communities with appropriate investment and support by governments and ESAs and the involvement of NGOs and private sector.

Issues

The Working Group identified four major areas that require consideration; namely:

- appropriate and cost-effective technologies;
- policies, planning and resource mobilization;
- national capacity building including training;
- watershed management and environmental protection.

In each of the above areas, a number of issues were identified as illustrated in the following table.

Appropriate technologies for communal water development and water conservation

Technology and Cost	Planning, Policy and Resources Mobilization	Capacity Building and Training	Watershed Management and Environment
Low cost technology for micro-dams and river diversion	Availability of data for planning and monitoring	Technical training of farmers, technicians and extension workers, demonstrations and promotion	Soil and water conservation technologies
Rehabilitation of existing small-scale irrigation schemes, water points, dams including traditional schemes	Planning process, including stakeholders participation and sustainability issues	Enhancing national capacity in identification planning, design and construction	Planning and development on watershed basis
Other issues : * Shallow wells including water abstraction from river beds * Equipment for land development * Water transport * River pumping for sprinkler and drips	Mobilization of local and external resources	Training for promotion of participatory approach	Policies on upstream and downstream beneficiaries
	Other issues ; * Resettlement * Compensation issues * Land and water user rights		Promotion of community involvement in watershed management

On the basis of the issues identified, the following action oriented recommendations were formulated.

Action oriented recommendations

To promote appropriate and cost-effective technologies

1. Prepare manuals on simple design and standards for micro-dam and river diversion structures including:

- site selection;
- design parameters;
- operation and maintenance; and
- on-farm water management.

Action to be initiated by appropriate government departments and implemented with support from ESAs, NGOs and other stakeholders.

2. Promote local manufacture of equipment for small-scale irrigation construction, such as improved manual, animal drawn and tractor powered compactors, transport carts, scrapers and scoops.

    This recommendation is directed to NGOs and the private sector.

3. Assess performance and status of existing small-scale irrigation schemes, water points, dams and traditional schemes and recommend action to improve their performance, rehabilitate infrastructure and restructure the management system.

    This action is to be undertaken by appropriate government departments in association with farmer participation.

To formulate policies, develop plans and mobilize resources

1. Select representative watersheds, assess existing data and, where necessary, equip such watersheds with instruments and measuring devices to generate complete agro-hydrological data that are required for proper design of micro-dams, water diversions, water and soil conservation structures, etc.

    This action is to be initiated by appropriate government departments with support from ESAs.

2. Incorporate, early in the planning and project design phases, provisions to monitor surface and groundwater quantity and quality changes and other associated environmental impacts in small-scale irrigation projects.

    This action is to be undertaken by government departments in association with NGOs and ESAs.

3. Create awareness of various technological options for small-scale irrigation development to stakeholders, with particular reference to farmers. This could be achieved by demonstrations and mass media use.

    This action should be initiated by government departments in collaboration with NGOs and the private sector with assistance from ESAs.

4. Initiate studies on rapid assessment of shallow groundwater potential and technologies for well construction.

    Action to be taken by relevant government departments with donor support.

5. Undertake studies on the relative roles of labour and machinery in small-scale irrigation construction in the context of cost reduction, employment generation, availability of labour and related socio-economic factors.

   Action to be taken by government departments.

6. Provide incentives such as provision of credit, easy access to inputs and legal recognition, to farmers to organize themselves into farmer organizations.

   Action to be taken by governments.

To build national capacity, including training

1. Provide in-service training to technicians and extension agents on construction, maintenance, operation of micro-dams and river diversions, well construction, on-farm water management and watershed management.

   Action by governments in collaboration with international donors and NGOs.

2. Train farmers in construction of micro-dams and river diversion structures and on-farm water management through in-situ demonstration. The training would be carried out by extension agents (who had previously undergone training).

   Action by governments, donors and NGOs.

3. Organize specialized training for engineers, graduates, national consultants and contractors on planning, design, site selection and construction of micro-dams and river diversion structures through TCDC and other appropriate mechanisms. Such training could be conducted in the countries of trainees and/or in countries where the expertise and experience exist.

   Action by governments, in close collaboration with donors and close connection with TCDC governments.

4. Implement training programmes to promote the participatory approach to small-scale irrigation development through well planned and short duration (2-3 days) workshops for stakeholders (local administrators, planners, engineers, agronomists, extension agents, farmers, rural community representatives and local NGOs).

   Action to be taken by national governments with the support of donors and NGOs.

To undertake watershed management and environmental protection measures

1. Develop policy guidelines that would enable watersheds to be considered as basic units for planning soil and water conservation activities and development of small-scale irrigation projects.

   Action to be taken by governments in collaboration with NGOs and ESAs.

2. Prepare manuals on soil and water conservation and water harvesting techniques and practices that are applicable to local conditions for use by extension agents, technicians, farmers and participating communities.

   Action to be undertaken by governments in collaboration with NGOs and ESAs.

3. Initiate pilot projects to evaluate options of incentives and other mechanisms that ensure equity of benefits to up-steam and down-stream communities;

   Action to be initiated by governments in collaboration with communities, NGOs and ESAs.

4. Create awareness of environmental impacts of watershed development to communities through campaigns and mass media programmes, thereby promoting community involvement in watershed protection measures that are directed towards the control of erosion, siltation, deforestation, overgrazing and water-borne diseases.

PART II

Technical papers presented in the Workshop

Summary of findings of missions in selected countries in East and Southern Africa

BACKGROUND

The importance of irrigation for increased food production and food security needs no emphasis. Thirty to 40 percent of the world's food comes from the irrigated 16% (about 250 million hectares) of the total cultivated land. There are wide regional variations in the proportion of irrigated agricultural land: 38% in Asia, 15% in Latin America; and 4% in sub-Saharan Africa. Total irrigated land on the African continent is estimated to be about 12.2 million ha. Six countries (Egypt, Madagascar, Morocco, Nigeria, South Africa and Sudan) account for nearly 75% of the total irrigated land in Africa. In sub-Saharan Africa, water control has, in the past, played a relatively minor part in agricultural development. However, this is now changing. Many sub-Saharan countries have realized the critical role of irrigation in food production. In these countries it is believed that a major part of new irrigation developments should be "small-scale", if they are to meet the household, local and national food security objectives, ensure equity and usher sustainable rural development.

Many reasons have been cited for the relatively low rate of irrigation development in sub-Saharan Africa. Some important ones are:

- relatively high cost of irrigation development;
- inadequate physical infrastructure and markets;
- poor investments in irrigation;
- lack of access to improved irrigation technologies; and
- lack of cheap and readily available water supplies.

A number of studies carried out on irrigation development in sub-Saharan Africa during the last two decades indicated that, among others, lack of access to affordable and water saving irrigation technologies, particularly by small-scale farmers, was a major constraint to irrigation development. The studies showed that lack of local capacity for manufacturing irrigation equipment and providing services had severely handicapped small-scale irrigation development. In general, imported equipment was frequently overpriced and not adapted to local conditions. Furthermore, equipment components did not match and spare parts were difficult to obtain. These studies concluded that there is an urgent need to solve the problem of "lack of access to improved irrigation technologies by small-scale farmers" in sub-Saharan Africa in order to promote increased food production and food security.

THE MISSIONS

FAO, in collaboration with the International Programme for Technology Research on Irrigation and Drainage (IPTRID) launched a series of missions to evaluate the status of

A. Kandiah
Senior Officer, Water Resources, Development and Management Service
Land and Water Development Division, FAO, Rome

irrigation technologies being practised by small-scale farmers in selected countries in East and Southern Africa. These missions also assessed the potential of improved and water-saving technologies to be transferred to and adopted by these farmers. The long-term objective of the missions was to promote sustainable low-cost irrigation technologies by: (a) enhancing the role of private sector in local manufacture of irrigation equipment, support services and marketing; and (b) testing and demonstrating locally manufactured equipment and improved technologies. The specific objectives were to:

- assess current status and trends of irrigation technologies (both modern and traditional technologies) with particular reference to small-scale farmers in public and private irrigation schemes;
- evaluate national capacity, with special reference to the private sector, for manufacturing, supplying and servicing of irrigation equipment, which are affordable (low-cost) and water efficient;
- assess the appropriateness of and opportunity for transferring the experience in manufacture, servicing and testing of irrigation equipment from the newly industrialized developing countries such as India and China;
- examine the possibilities for establishing regional and/or national centers to demonstrate and disseminate improved irrigation technologies; and
- prepare appropriate reports containing the findings of the missions and recommendations, including elements for national action programmes.

The following table presents further information concerning the missions.

Country	Date and duration of mission	Composition of mission team
Tanzania	June 96, 5 weeks	3 international consultants + 1 national consultant
Malawi	June/July 96, 3 weeks	3 international consultants + 1 national consultant + 1 FAO staff member
Zambia	July 96, 3 weeks	3 international consultants + 1 national consultant
Zimbabwe	July/August 96, 3 weeks	3 international consultants + 1 national consultant + 1 FAO staff member
Ethiopia	June/July 96, 4 weeks	1 national consultant
Kenya	January 97, 3 weeks	1 national consultant + 1 World Bank staff member

FINDINGS OF THE MISSION (TANZANIA, MALAWI, ZAMBIA AND ZIMBABWE)

The mission identified a number of factors that affect small-scale irrigation development in general and adoption of improved irrigation technologies by small-scale farmers in particular. Three major factors were:

- cost of irrigation and irrigation equipment;
- capacity of farmers to invest in improved irrigation technologies;
- constraints to local manufacture and servicing of equipment

Cost of on-farm irrigation and irrigation equipment

In general and in comparison with Asian countries, such as India, the cost of on-farm irrigation (capital of irrigation equipment, maintenance, labour and energy costs) is high in East and Southern Africa. It varies from one country to another, and with the crop, cropping

intensity, the type of pump and irrigation method. The following table summarizes the findings.

Cost of on-farm irrigation per ha per year in US Dollars (traditional surface irrigation)

Country	Crop and cropping intensity	Type of pump		
		Treadle	Diesel	Electric
Tanzania	Maize, 100% CI	126	306	190
Malawi	Maize and beans, 150% CI	280	1458	1311
Zambia	Maize, 100% CI	156	320	223

In Zimbabwe, on the other hand, annual irrigation costs per ha were (an assumed cropping intensity of 200%):

- US$ 1 654 for sprinkler irrigation;
- US$ 1 553 for drip irrigation;
- US$ 1 600 for gravity (surface) irrigation;
- US$ 2 752 for collector well system.

Capacity to invest in improved irrigation technologies

In Tanzania, Malawi and Zambia, small farmers account for 80 to 85% of the farming population. Most of them are dry-land subsistence farmers. However, provision of irrigation and improved irrigation technologies and crop husbandry practices has the potential to transform these farmers into economically viable and substantive farmers. The constraints to adoption of improved farming practices are:

- poor resource base (equity);
- crops are produced mostly for consumption (no surplus);
- fragmented and non-uniform farm holdings;
- small area of farm land per family;
- lack of land title;
- poor financing and credit facilities;
- wherever irrigation water is provided, water use efficiency is poor (often less than 30%);
- inadequate transportation and marketing facilities;
- high cost of imported equipment.

However, in Zimbabwe, the situation is relatively better and there is clear evidence of successful smallholder irrigation. The success of the commercial farming sector has impacted on the smallholders. For example, sprinkler irrigation is used in about 10% of the 6 000 ha of smallholder farms. In a number of gravity irrigation schemes, the farmers are able to pay for the maintenance of irrigation schemes. Marketing and credit facilities are relatively better.

Constraints to local manufacture and servicing of equipment

The following constraints generally apply to all four countries, namely, Tanzania, Malawi, Zambia and Zimbabwe.

- *High import duty:* Many local equipment manufacturers complain that high import duty on raw material/unfinished products is a major constraint. This import duty amounts to: 45% in Tanzania; 20% (surtax on irrigation equipment) in Malawi; 15% import duty and 25% VAT in Zambia; and in Zimbabwe, 0-60% on raw material and 0-40% on raw material, if specifically for irrigation equipment.

- *Inadequate electric power:* Access to electricity by farmers is poor and this inaccessibility affects the adoption of electric pumps and improved technologies that may require electricity. For example, rural electrification is only 5% in Tanzania, and 10% in Malawi. In Zambia, electricity supply is limited to towns although there is ample supply and the cost is low. In Zimbabwe, the situation is relatively better.
- *Inadequate credit system:* Inadequate credit facilities to import raw material and finished products affect the local manufacturing capacity and equipment dealers' ability to meet the full needs of farmers. In addition, interest rates for credit are very high. In Tanzania, Malawi and Zambia, this interest rate varies between 40% and 60%. In Zimbabwe, it is about 32%.
- *High cost of skilled labour:* Many local manufacturers reported that the cost of skilled labour is so high that they are unable to manufacture equipment locally at affordable prices, particularly when the demand for locally manufactured equipment is not so great.

Locally manufactured versus imported equipment

Currently, simple irrigation equipment such as hand-pumps and, in some cases, pipes are manufactured in most of the East and Southern African countries. The situation is summarized in the following table.

Irrigation equipment manufactured in East and Southern African countries

Country	Local manufacture	Imported	Comments
Tanzania	Hand pumps for domestic water supply (Tanire) for shallow bore-holes	Deep well pumps, mono-bloc and submersible pumps, and irrigation equipment	Equipment is mostly imported from European countries and from South Africa.
Malawi	Hand pumps including rope and washer pumps. An attempt is being made to manufacture treadle pumps.	All mechanical and electric pumps are imported. Light weight sprinkler pipes are imported.	There is interest for local manufacture, particularly through joint venture.
Zambia	Treadle pumps are manufactured. PVC pipes are also manufactured.	Irrigation pumps are imported from South Africa, Zimbabwe, Europe, India and China.	There is keen interest to manufacture equipment locally. There is also interest to import from or start joint ventures with Indian companies.
Zimbabwe	Sprinkler and micro-irrigation equipment is manufactured. Capacity to manufacture all types of pumps, pipes and equipment is good.	Many components of irrigation equipment are imported. Most imports are from Europe and USA.	Irrigation equipment is still expensive.

It was observed that importation of irrigation equipment from Asian countries will make this equipment available to smallholders at an affordable price. Local suppliers are cautious of the quality of equipment from Asia. Quality can be controlled through an equipment testing programnme such as the one available in Zimbabwe.

IRRIGATION TECHNOLOGY IN ETHIOPIA

Rainfed agriculture is the dominant form of farming in Ethiopia. Although traditional irrigation was practised in the highlands for centuries, it was only in the early 1950s that modern irrigation technologies were introduced to Ethiopia. The technologies were adopted in large private and government owned schemes, primarily in the Awash River Basin. Most of the early schemes were pump-irrigation projects, but later gravity irrigation schemes were

introduced. In all cases, the irrigation method was surface irrigation, predominantly furrow irrigation for cotton and wheat and basin irrigation for commercial fruits such as bananas. Some private farms had installed hydraulic rams on the banks of the Awash river to lift water. In the mid-1970s, windmills and hand pumps were introduced to lift water from boreholes, mainly to supply water for drinking, domestic purposes and for community gardening.

Modern water lifting technologies

The following water lifting technologies have been adopted by farmers with varying degrees of success.

- *Hydraulic rams*: Hydraulic rams were installed by private farmers in the Upper Awash valley about 20 years ago to irrigate horticultural crops. They are not widely used today.

- *Hand pumps*: Locally manufactured (the Akaki Pump Factory) hand operated reciprocating pumps were widely introduced in Ethiopia by NGOs for drinking and domestic water supply. Design and local manufacture of animal drawn pumps are also being pursued.

- *Windmills*: Windmills were introduced in areas where wind regimes are favourable such as in the Rift Valley areas. In Zeway and Ogadan, windmills are still operational, but mainly for potable water supply.

- *Mechanical pumps*: Large centrifugal pumps were used by the State Farms in the Middle and Lower Awash to irrigate cotton. Recently, diesel powered centrifugal pumps were purchased from India to irrigate pastures in the Middle Awash. Electric motor driven pumps have also been imported from North Korea. Small to medium sized centrifugal pumps are produced locally by the Akaki Pump factory.

On-farm irrigation methods

Surface irrigation methods were the predominant form used. On some large-scale farms, sprinkler irrigation has been used, some examples are the Anger State Farm in the West, the Zeway farm in southern Ethiopia and the Fincha Sugar Estate. Recently, drip irrigation was introduced and practised on a government farm in Zeway and two other small commercial farms.

Opportunities and constraints

There is potential for improvement or introduction of irrigation technology in Ethiopia. In 1987, the consultancy firm Tahal and Shawl conducted a survey of traditional schemes in different parts of the country. The survey revealed that irrigation works in Ethiopia are in a rudimentary state and are invariably unsatisfactory for performing improved irrigation practices.

- The diversion structures built by the farmers are washed out during each flood and have to be reconstructed very frequently.

- Since the irrigation networks are not properly aligned, they are exposed to erosion and siltation, consequently, they do not function properly and require frequent repairs.

- In the traditional scheme, the diversions are not provided with control structures, and thus the farmers do not have any regulating mechanism over the water supply. The efficiency of water distribution in the fields is low because land levelling is not practised.

- The irrigation system losses are very high.

In spite of the less extensive area of irrigation in the country and shortage of skills in irrigation, the willingness to accept new or improved technology by the farmers is quite high. This observation was made during discussions with farmers who are currently using traditional irrigation methods. Many of these farmers are aware of the benefits of modern irrigation technologies, and they readily welcome new technologies or improvements which can bring more benefit to them by improving crop yields and reducing labour requirements.

However, the problems and constraints to adoption of improved technologies should be recognized. The problems are related to factors such as economic status of the farmer, skills in different aspects of irrigation, land use right, and marketing.

- Development of irrigation is an expensive venture for the farmers in view of their low per caput income. The cost of purchasing, installation and operation of equipment is beyond the economic capacity of many individual farmers.

- Diversion structures tend to be large and difficult to construct. Locally developed pumps tend to be expensive, costing over Birr 10 000 each. Farmers must, therefore, organize themselves into groups, to provide the required finance and manual labour for the construction and maintenance.

- Many farmers cannot provide the required finance for irrigation schemes. They require assistance from the government or other organizations such as the NGOs. In the absence of such support, credit facilities must be provided. Although the Agricultural and Industrial Development Bank provides loans to agricultural schemes, water user associations have to attain legal status to benefit.

- For the purpose of optimizing the investment made in irrigation schemes, farmers need inputs such as improved seeds, fertilizers, pesticides and implements. The cost of procurement of these inputs is beyond the economic capacity of the farmers.

- In view of the recent history of forced collectivization, many farmers are not willing to establish permanent works or make financial expenditure on land. Farmers need to be guaranteed legal right to land in order to undertake more permanent works such as irrigation.

- The absence of adequate market outlets for the produce obtained from irrigation schemes is another major constraint to the development of irrigation projects.

Local manufacturing and servicing capacity

Some government departments, such as the Institute of Agricultural Research (IAR), some projects under the Ministry of Agriculture and the previous Water Resources Commission (WRC) have been conducting research and development activities to develop or improve, as per their respective mandates, various equipment, implements, and tools for agricultural

works. The private sector produces various pipes, and fabricates gates from sheet metal and angle iron.

There is potential for local manufacture and the adoption of the following simple water lifting devices in Ethiopia.

The swing basket	The Persian wheel
The don	Rope and bucket lift
Archimedean screw	Circular two bucket lift
The water wheel	Counterpoise bucket lift

In areas where diesel or electric power is not available, any one of the above devices can be used. However, since these devices are not familiar to farmers, the skill to construct and operate them is lacking.

Modern water lifting devices such as pumps, are being introduced into Ethiopia. Research to develop prototype hand pumps and animal powered pumps has been in progress for several decades. IAR designed, fabricated and tested a hand pump and an animal powered pump. However, the centre did not pursue the production of this equipment for commercial purposes.

Recently, the Engineering Design and Tool Enterprise produced and demonstrated an animal driven pump and is expecting orders for mass production.

Wind operated pumps were introduced to the country by the NGOs in areas where wind is dependable. However, the components were all imported and no attempt was made to manufacture them locally.

Similarly, solar energy driven pumps using solar panels were installed in some localities (for example near the town of Mojo) for water supply purposes only. The capacity to manufacture these pumps locally is too remote to consider.

On the other hand the capacity to manufacture water control gates has been developing locally. Most of the gates installed by the 10 200 ha Amibara Irrigation project in the early 1980s, were fabricated by the Arefaine Metal Works in Addis Ababa using sheet metal and angle iron.

Water flow measuring structures such as Parshall flumes and staff gauges were also manufactured locally using designs produced by engineers. Parshall flumes of varying sizes were used for water management works as well as for irrigation project studies. The staff gauges manufactured locally were installed in the Amibara Irrigation Project.

Concrete pipes of various sizes or diameters are being manufactured in different parts of the country for different purposes. At the Arba Minch State farm concrete pipes were used for water distribution.

The Thermoplastic Factory at Addis Ababa produces various sizes of pipes for different uses. The PVC Manufacturing plant in Addis Ababa also produces pipes of different sizes for water supply and water conveyance.

The Nazareth Plastic Factory produces a range of rigid and flexible tubes and joints for irrigation and drainage works.

The Ethio-Plastic Factories in Addis Ababa also produce flexible hoses of different sizes, which can be used as flexible siphons for abstracting water from field canals into fields.

The Akaki Pump Factory produces electric as well as diesel engine powered centrifugal pumps which are used for various purposes. After sales services are provided by the Akaki pump factory personnel as well as by agents of the foreign suppliers. The Akaki Pump Factory sends technicians to the pump sites at the customers' request to assist in selecting the proper pumps for the particular site, as an after sales service. The technical personnel of the factory install, commission and also train the operators for the client. The pump factory keeps adequate stock of spare parts both for the centrifugal pumps and the Lombardini engines.

Scope for improvement

Rehabilitation and/or modernization of existing irrigation schemes through the provision of improved diversion structures, proper canal and drainage systems as well as water flow control structures such as checks, offtakes and gates, will improve efficiency of irrigation and water productivity. Coupled with improved market facilities, these improvements can contribute to successful irrigation schemes.

Appropriate technologies for a particular environment are those that can be "grafted" on to an existing farming system. Accordingly, the technologies introduced must be affordable to the beneficiaries. Further, they must be simple enough to be operated by the farmers.

An assessment of the irrigation methods, diversion works, control structures and the conveyance system currently being used in Ethiopia indicates that there is substantial room for improvement. To effect this improvement, appropriate technologies should be selected and introduced on the basis of available resources, technical skill and management capabilities of the farmers. Farmers should depend less on other institutions for operation and maintenance of the system. Also, the recurrent costs should be low enough to be paid by farmers.

Unsophisticated, easily adapted technologies from developing countries should be used to improve irrigation system design and construction. Farmers can construct a simple diversion structure, either rockfill or silo type on small streams, under the guidance of the irrigation extension workers.

Where irrigation water is drawn from shallow groundwater, a number of simple, but efficient water lifting devices in use in "relatively advanced" developing countries can be introduced. Open wells are quite common in Ethiopia, and are sources of supply for domestic use and small gardens in villages. A range of affordable water lifting devices can be introduced to lift water from such open wells.

When farmers have the capacity to pool their resources to purchase animal driven, hand operated or centrifugal pumps, an integrated extension support service should be provided for farmers. Extension support should include, agronomy, irrigation technology as well as marketing. Inputs such as fertilizers and improved seeds should also be made available. Credit facilities should be arranged through appropriate banks.

Farmers should be educated and trained in the principles and practical aspects of irrigation. This training should be effected through regular workshops, where experts or extension workers orient the farmers towards the various aspects of irrigation management. The workshops should be augmented by exhibitions, demonstrations and film shows produced in the local languages.

Conclusions of the Ethiopian study

- Traditional and modern irrigation technology can contribute substantially to enhancing the production and productivity of irrigation schemes.
- Smallholder farms in particular are constructed with rudimentary levels of technology and provide the greatest opportunity for improvement. The introduction of improved technology is likely to encourage irrigation development in new areas which were previously not attempted due to lack of know-how or facilities.
- Introduction of irrigation technology can be made successful if the main actors of technology transfer, namely, the technician, the extension staff, and the farmers are all convinced of the merits of the technology and if the technology is carefully selected, developed and tested, and supported by appropriate policy and institutional framework.
- It is recommended that the Arbaminch Water Technology Centre be selected to serve as a national centre for irrigation technology, following the establishment of a formal section to undertake the additional functions. It is also recommended that the programmes of the national centre for irrigation technology be guided by a board representing the various stakeholders.

OVERALL SUMMARY OF FINDINGS OF THE MISSIONS

- The cost of irrigation equipment, imported, manufactured and/or assembled locally was to 2 to 10 times higher than in Asian countries, depending on the equipment. For example, the cost of a locally manufactured treadle pump in Malawi and in Zambia was respectively, 200 and 400% more than in Asia. Imported diesel pumps (2-5 HP) in Tanzania, Malawi and Zambia was 200 to 300% more than the cost in Asia. This is illustrated in the following table.

Cost of irrigation equipment imported from Europe and Asia (US$)

Equipment		Tanzenia	Malawi	Zambia	Zimbabwa	Asie
Hend pump	Local	400-600	-	-	-	
	Imported	-	-		600	40-110
Treadle pump	Local	-	100	160	-	
	Imported	-	-	-	40-65	
Rope & washer	Local	-	-	-	180	-
	Imported	-	-	-	-	-
Diesel engine (2-5 HP)	Locel	-	-	-	6000	600-700
	Imported	2000	1000	200	(15 HP)	-
Centrifugal (1-5 HP)	Local	-	-	-	400-1500	-
	Imported	700-3000	2800	650-700	400-1500	150-320
Submersible (1-5 HP) Imported	Locel	-	-	-	-	-
	Imported	200-4500	2000	2500-4400 (3-10 HP)	4000-9000 (10-15 HP)	350
Sprinkler system (per he.)	Local	-	-	-	1500	-
	Imported	2000-2500	2000-3000	2000-4000	2000	1000-1200

Notes:

1. Cost of hand/manual pumps from Southeest Asia rafers to averaga cost in Viet Nam/Nepal/Bangladesh/ India.
2. Cost of mechanical pumps rafers to Indian pumps.
3. In the cese of Asie, it is the cost if imported and includes the prevailing import duty, ship clearence cherges, etc.

- The factors which adversely affect local manufacture and servicing of equipment were identified as follows:
  - high import duty, particularly for raw materials;
  - inadequate electric power;
  - inadequate credit;
  - high interest rate on lending;
  - high cost of skilled labour; and
  - poor local demand.

- The following major constraints affect the capacity of farmers to invest in improved irrigation technologies:
  - poor resource base of farmers;
  - fragmented and small size of land holdings;
  - unsecured or lack of land titles;
  - high interest rate of bank financing;
  - poor performance of gravity irrigation systems; and
  - poor transportation and marketing facilities.

- Despite the above limitations, there seems to be an emerging interest among local entrepreneurs and the farming community in improved irrigation technologies. An appropriate stimulus could lead to enhanced local manufacture of equipment and adoption of improved irrigation technologies by farmers.

- The following technologies were identified as appropriate for transfer from Asian countries and elsewhere to individual farmers, small farmer groups and community farmer groups (farmers associations):
  - treadle pumps and other manual pumps, including animal powered pumps and hydraulic rams;
  - low-cost drilling technologies such as sludge/slurry and water compression drills, and hand/auger drilling;
  - water harvesting structures such as micro-dams/tanks in association with check dams (percolation tanks) in the watershed;
  - sprinkler irrigation including conventional systems and drag- hose systems;
  - micro-irrigation systems such as pitcher irrigation, porous clay pipes, micro-sprinklers, bubblers, drips; and
  - demonstration of technologies at established centers or on farmers' fields.

RECOMMENDED ACTIONS

Technologies for individual or small groups of farmers

- ***Treadle Pumps:*** Treadle pumps are well suited to lift water from shallow water bodies (either shallow groundwater or shallow streams). These are appropriate to many East and Southern African countries. Zambia has the largest potential (southern, western, northern and north-eastern provinces have suitable areas) followed by Malawi (all 8 agricultural development divisions), Tanzania (10 project sites) and Zimbabwe (selected dambo areas, vegetable areas around Harare). In the first year, 500-1 000 pumps can be installed in each country, though the number in Zimbabwe might be less. By the fourth year, 3 000 to 5 000 pumps can be installed annually in each country with the exception

of Zimbabwe. To implement this installation, some dedicated and interested NGOs should be encouraged to promote marketing and dissemination of the technology in each country.

- ***Drilling technologies*:** Low-cost drilling technologies such as slurry, sludge or water compression or hand auger/drilling methods could be introduced in many East and Southern African countries to promote improved well construction. These technologies would have long-term application for both irrigation and water supply for drinking and domestic purposes.

- ***Low-cost drip/sprinkler with shallow wells*:** In many cases, individual farmers pump water from shallow streams or shallow wells and irrigate small plots by surface irrigation (wasting much water) or apply water by hand (involving much labour). In such cases, simple low-pressure sprinklers or drip systems could be introduced. Water could be collected in a raised drum and could be conveyed through PVC lateral pipes to sprinklers or simple drippers. This method will cover twice the area that is normally covered by surface irrigation methods. The cost of such a system would be about US$ 100 per 1000 m^2.

Technologies for a group of farmers

- ***Small tanks and check dams*:** In many East and Southern African countries, there is good scope for small tank construction. The size of the tank will depend on the terrain, rainfall regime, number of farmers in the group and the land available for irrigation. The upper storage limit of such tanks would be about 1 million m^3, with a majority in the range of 100 000 to 500 000 m^3. Such tanks are successfully used in many parts of Asia, particularly in India and Sri Lanka. Approximate cost is in the region of US $ 800 to 1000 per ha.

  Construction of such irrigation tanks should be complemented with the construction of check dams in the catchment area to check erosion and siltation of the tanks. Check dams will also increase the recharge of shallow aquifers. Cost of check dams vary from US$ 500 to 1000 per structure.

- ***Sprinkler irrigation schemes*:** The encouraging results from the first few schemes in Malawi have led the Department of Irrigation (DOI) to tender the design and construction of 56 small-scale sprinkler schemes, 12 ha each.

  However, the present capacity of the DOI is inadequate to supervise and monitor these schemes and it needs to be strengthened. An on-the-job training programme of relevant staff would be appropriate.

  In Zambia, in view of the limited experience in small-scale irrigation, and the lack of experience with sprinklers, it is proposed that approximately four demonstration farms be established in appropriately selected locations, for technical and extension staff of the Ministry of Agriculture and farmers. The estimated cost of a demonstration farm would be US$ 3000 per ha.

- ***Drag-hose sprinkler system:*** In view of the water scarcity in many parts of Zimbabwe, especially in agro-ecological regions III, IV and V, where 60% of communal farms are located, the use of drag-hose sprinklers by such communal farmers would be appropriate. The cost of drag-hose sprinkler system is about 30 to 50% of the cost of surface irrigation systems. There would also be a 40% water saving.

- ***Drip and pitcher irrigation*****:** In the southern and eastern provinces of Zambia, pilot drip and pitcher irrigation could be demonstrated. Currently, surface irrigation is practised in these areas with much wastage of water. In addition, surface irrigation systems cost US$ 5 000 to 7 000/ha. It is suggested that four pilot demonstrations be started. Two of these locations would use treadle pumps to lift water and apply it to crops by pitcher/clay pipe irrigation. In the other two locations, water may be lifted by treadle or small mechanical pumps and applied to crops by drip systems.

  In Zimbabwe, it is proposed that two pilot drip irrigation schemes be initiated in two districts to cover an area of about 50 ha per scheme. One of them initiated for tree crops and the other for vegetables. The estimated cost would be around US $ 3000 per ha excluding the construction of the dam.

- ***Irrigation equipment manufacture*****:** Most irrigation equipment in Tanzania, Malawi and Zambia are imported from Europe (including Israel), USA and South Africa. However, in Zimbabwe most irrigation equipment are locally manufactured, but the cost is relatively high.

  In Tanzania, hand pumps are locally manufactured at a relatively high cost. In Malawi and Zambia, PVC pipes are manufactured respectively by the PROMAT and COWLYN companies.

  In all countries, joint ventures with selected equipment manufacturing companies from Asia (India and China) could result in greater availability of equipment at an affordable price. A number of local equipment dealers have expressed interest in joint ventures.

- ***National irrigation demonstration centres*****:** Demonstration of performance of irrigation equipment and technologies is the key to technology transfer and adoption. Demonstrations will enable assessment of performance of locally manufactured and imported equipment under local conditions as well as serve as tools for training technical and extension staff as well as farmers. In all the countries, where the study was undertaken, with the exception of Malawi, the mission has identified existing physical facilities which could be upgraded to national irrigation equipment and technology demonstration centres. In Tanzania, it could be the Agricultural Training Centre at Moshi; in Zambia, the National Irrigation Research Station at Nanga could host the demonstration centre; in Zimbabwe, the Irrigation Technology Centre would provide an excellent site for irrigation demonstration; and in Ethiopia, the Arba Minch Irrigation Technology Centre will be an ideal site to establish the irrigation demonstration unit.

Potential for small-scale irrigation in sub-Saharan Africa: the Kenyan example

FAO/IPTRID missions have found that lower-cost, more water-efficient irrigation technologies have the potential to greatly expand small-scale irrigation in East and Southern Africa and significantly improve food security and family incomes. Kenya is doing better than most other countries in the sub-region in developing and adopting these technologies. There, supplementary irrigation is transforming subsistence farmers into commercial agents. The opportunities and constraints faced by Kenya in revolutionizing small farming through better irrigation technologies provide some important lessons to other countries and to the donor community about how to proceed along this "new frontier". This brief presentation is meant to highlight a few of these lessons.

TECHNOLOGIES

Traditional irrigation in Kenya dates back some 400 years, longer than that of most countries in East and Southern Africa. Today, Kenya is well ahead of other countries in the sub-region in utilizing low-cost technologies for small-scale irrigation (defined here as irrigation on small plots where farmers have the major controlling influence and using a level of technology which farmers can effectively operate and maintain - Carter, 1994).

Kenya's total irrigated area is about 80 000 hectares. Public and private small-scale irrigation is still less than 50 000 ha. This is still very small compared to the estimated potential of more than 300 000 ha.

Many different technologies and techniques are used for water collection and distribution for small-scale irrigation in Kenya, including rainwater harvesting, bucket irrigation, gravity fed sprinkler and drip, treadle and pedal pumps, rope and washer, motorized pumps, windpower and construction of small earthen dams.

Inexpensive and simple gravity and pump sprinkler systems for horticultural crops have been extremely profitable investments. Their numbers are growing fast in high-potential areas such as on the slopes of Mt. Kenya where commercialization of horticultural crops for domestic and international markets is in full swing. However, the spread of this technology to cover most of the estimated potential irrigated area is limited by physical conditions and increasing competition for water.

R. Purcell
IPTRID Program Manager, World Bank, Washington D.C., USA

Interestingly, irrigation development on the slopes of Mt. Kenya first began when families started developing the mountain's streams for domestic water supply. Farmers quickly tapped into the cement and PVC pipe conveyance systems with additional piping and sprinkler distribution, often using locally made "Juakali" sprinkler units produced in the nearby towns and sold for about $2 each.

Use of the pedal pump on valley bottoms is also growing fast. The pedal pump is an adaptation of the Asian treadle pump by a local NGO (Approtech). Basically, a Bangladeshi/Indian treadle pump has been reconfigured into a lighter, portable pedal pump. Nicknamed the "Moneymaker," these sell for about US$70 and are actively marketed in towns and villages. The pump is most appropriate for smaller, subsistence farmers who see the opportunity to expand irrigation on small plots by 50 percent more than their existing irrigated area. While US$70 may appear expensive, most of these farmers have an extended family network in the village and nearby towns from whom they are able to borrow.

Over a two-month period in 1996, when the pedal pump was introduced, Approtech sold more than 300 pumps and has had difficulty keeping up with demand. At the moment, local contractors can make only about 100 units a month. Approtech hopes to provide technical support services and credit to raise production capacity to about 500 pumps a month over the next two years.

Low horsepower, diesel pumps are also very popular among farmers who can afford them, especially those growing French beans, snow peas and other crops for export. The engines are imported (some of the housing is locally cast) and the pumps are not inexpensive - typically selling for US$700-US$900 for 3-5 hp pumps.

There may be opportunities for farmers to band together and collect savings to buy and share more expensive equipment. However, while farmers in Kenya often pool their resources to pay for conveyance systems, they are extremely reluctant to share pumps.

Opportunities

Farmers who are using the technologies described above are doing very well - the sprinkler and engine users in absolute terms, but the pedal pump users are also relatively much better off. Women, who do most of the field work, are gaining greater earning power. In addition, the success of the pump technology is attracting a younger generation back to the farms. One young farmer had just completed police training camp only to return to his small family plot to grow French beans and onions.

The income gains from commercialized farming through small-scale irrigation in Kenya are impressive. The average smallholder on 2-3 ha of rainfed land makes less than US$ 750 farm income. Compare this with per hectare gross margins of US$ 1 400 for snow peas and French beans, US$ 450 for kale and US$ 600 for onions. These farmers get 2-3 crops a year.

Constraints

Given the above figures, why is there no revolution in pump technology and small-scale irrigation in Kenya and elsewhere in the sub-region? The answer is that the constraints remain

daunting. The constraints are presented in order of importance, first from the farmers' perspective and then from the manufacturers'.

1) *Financing*: Equipment costs, especially motorized pumps, are still high. Most equipment require a substantial cash outlay. Small farmers do not have collateral to safeguard loans either from the government agricultural finance corporation or from commercial banks. NGOs have in recent years, provided small loans to groups whose collateral is pcer pressure, but these do not have sufficient capital to expand and probably cannot administer such loans profitably on a commercial basis (see the paper on SISDO).

2) *Marketing*: Crops are marketed in many ways: directly by farmers to consumers in local markets, through cooperatives, through middlemen, and through export contracts. Except when farmers have firm contracts with exporters, there are big risks. Market information is lacking so that farmers who transport their produce to a distant town may find the market flooded. There are serious problems with cooperatives that fail to pay farmers or are rife with mismanagement and sometimes corruption. There are problems with middlemen who take advantage of what has been a breakdown in the cooperative system in Kenya. These middlemen pay high prices to rope the seller in and then return the next season to pay low prices after the farmer has severed ties to traditional buyers. Middlemen are only taking advantage of government failure. Clearly, farmers need some protection, probably in the form of better market information.

Manufacturers of low-cost equipment face a host of problems. Overall, the government has put a lot of effort into crop and livestock research; much less effort has gone into support for agricultural engineering. Thus, knowledge and capacity for technology development and application are lacking. Furthermore, government policies and financing has favoured the development of a private sector that depends on expensive equipment imported from abroad. While there is impressive development of low-cost equipment by small-scale entrepreneurs, including the "Juakali" artisans producing equipment like low-pressure butterfly sprinklers and pedal pumps, this industry is handicapped by lack of access to credit and poor distribution systems. Overall, there remains little national awareness of innovative, lower-cost technologies and their possibilities. The pump importers are also severely handicapped by strict borrowing conditions, heavy income taxes, high cost of input materials (including high import duties), and restrictive import licensing. Marketing, distribution and servicing of equipment is poor. Pump breakdowns are a major problem; farmers are not trained to maintain pumps and do not generally carry spare parts.

GOVERNMENT'S ROLE

This Workshop should principally address governments' role in overcoming these constraints and enhancing small-scale irrigation development and technology uptake by small industry and small farmers.

First, it should be stressed that the government does not have a very positive role to play in building and managing irrigation schemes, whether they be large or small. The Kenya experience demonstrates that farmers do much better when they build, own and operate the schemes themselves. Public, large and small schemes perform much more poorly than private schemes in which farmers feel they have more at risk. (Farmers begin with very high

expectations in government-built schemes and are quickly disillusioned when things do not work and assistance is not forthcoming.)

The government does have a critical role to play in creating an enabling environment for technology development and uptake for small-scale irrigation.

- Government should develop policies and regulations that influence irrigation equipment manufacture, importation, promotion and servicing. Lower priced imports and joint manufacturing arrangements should be encouraged

- Government should develop policies and mechanisms to facilitate access to credit by small farmers.

- Government can also play a direct role in extension service training and provision of other technical support services, like training on small-dam construction, scheme design and the production of manuals for design and management of micro-dams and water diversion structures.

- Government can assist agricultural universities to strengthen their programmes on irrigation through short-courses and research and innovation grants.

- Government can assist in testing and demonstrating equipment at universities and demonstration centers.

- Government can mobilize real-time information on markets and convey it to farmers' associations and can facilitate the creation of farmer networks to disseminate and utilize such information. This is an extremely important function in countries like Kenya, with potentially large markets. However, the development of even rudimentary markets in countries like Malawi, where potential is smaller, is also critical.

Objectives of the Workshop

It is hoped that in the group working sessions which are a part of this Workshop, specific ways in which government can act will be developed. Specific ways in which donors can assist (not only governments directly), but NGOs, the private sector and farmers themselves should also be recommended. Outline 3-4 pilot interventions in particular countries where the government and donors have particular interests. Think in innovative ways and realistically about what various actors can do to promote technology uptake.

For example, take the question of government capacity to support technology development and adoption. The absence of such capacity in almost every country in the sub-region is one of the biggest challenges in making a success of efforts in this Workshop and beyond.

Take a close look at this problem. In an environment where it is not realistic to think that there will be huge government budgets for increased capacity in areas like extension and technical support; where there may not be a standard package of technology to apply with one goal in mind - to maximize yield per unit of land for one or two stable crops; where farmers are not relying on agriculture for subsistence - how can farmers be supported? What lessons

are there from other parts of Africa? Perhaps there are lessons from Kenyan farmers who receive support services through their export agents? Perhaps there are lessons from Zimbabwe where some farmer organizations provide their own services. Perhaps, too, think of examples from developed countries where networks of farmers exchange information and expertise, led by the most progressive farmer and the one with the best-performing technology can be developed.

CONCLUSION

Populations throughout sub-Saharan Africa are growing. Traditional methods of support to agriculture have largely failed, and by the year 2025, there will be 1.2 thousand million people who will need 300 million tons of grain. How can an impact be made on irrigation, irrigation technology, associated support services and in other areas? Business as usual in technology generation and adoption, support services, marketing and credit has not worked on rainfed lands. What can be done differently in irrigation?

Today in Kenya, farmers want to overcome their traditional isolation. They want to know about useful technologies. They want them to be available and affordable. They want to be taught how to use them. What help can be provided? It is hoped that, over these next few days, some answers can be developed.

Creating an enabling environment for the uptake of low-cost irrigation equipment by small-scale farmers

It is estimated that 15 million ha of land are currently under irrigation in sub-Saharan Africa. This hectarage represents two percent of all cropped land, as compared to 29% in Asia or 15% globally (Barghouti and Moigne, 1990), see Table 1. These figures do not only demonstrate inadequate levels of infrastructural investment in Africa, but they also underscore the unwarranted level of pessimism over prospects for viable irrigation development in Africa. Some of the reasons for the poor performance of irrigation will be discussed in this paper. More importantly, however, this paper will build on a growing body of research-based knowledge demonstrating that there are indeed high levels of economic return to the right type of irrigation investment in Africa. This paper will explore characteristics and qualities of such viable irrigation and discuss the factors leading to a more conducive environment for economically viable irrigation development in Africa. Examples will be drawn largely from South and Eastern Africa.

The preference for large and specialized irrigation systems by African governments and donors alike, is arguably the most serious error of economic judgement with respect to irrigation. There is, of course, an assortment of other reasons. It can be argued however, that large systems are generally incompatible with most African smallholder farming systems. These large systems fit the operational styles of Africa's top down, over-centralized public sector organizations. Support services for farmers, such as extension and credit, are therefore ineffective. Large, state-imposed systems often alter the established patterns of land tenure and land settlement, and have the effect of disrupting or undermining the established traditional economic institutions. The scenario painted so far can be summed up in the current prevalence of inappropriate irrigation systems, alien to most African farmers, state driven, poorly integrated with the local economy and trade markets, and poorly supported by an array of ineffective public organizations. Some of these problems will be elaborated upon later.

Before elaborating on the negative, one needs to paint a positive picture that is emerging in African irrigation development. In general, smallholder irrigation is showing greater financial and economic viability. Smallholder irrigation is even doing better where the system is owned and operated by the farmers. Smallholder irrigation is better integrated with rainfed systems, if farmers are able to either develop their own individual water source or run their irrigation more independently of other farmers in terms of management decisions, such as what to grow and when to water. Farmers in such situations achieve a higher return to their set of limited resources. The scenario painted with smallholder irrigation, in summary implies

Mandivamba Rukuni
Professor of Agricultural Economics
University of Zimbabwe

TABLE 1
Sub-Saharan Africa: astimatas of irrigated areas, 1987, in relation to irrigation potential

Area developed: country	Irrigation potential 1992	Modern (thousands of ha)	Small-scale or traditional	Total	Developed as % of potantial
Angola	6700	0	10	10	<1
Benin	86	7	15	22	26
Botswana	100	0	12	12	12
Burkina Faso	350	9	20	29	8
Burundi	52	2	50	52	100
Camaroon	2430	11	9	20	8
Central African Republic	1900	0	4	4	<1
Chad	1200	10	40	50	4
Congo	340	3	5	8	2
Equatorial Guinaa	n.a	n.a	n.a	n.a	n.a
Ethiopia	670	82	5	87	13
Gabon	440	0	1	1	<1
Gambia	72	6	20	26	36
Ghana	120	5	5	10	8
Guinea	150	15	30	45	30
Guinea Bissau	70	n.a	n.a	n.a	n.a
Ivory Cost	130	42	10	52	40
Kenya	350	21	28	49	14
Lesotho	6	0	1	1	13
Liberia	n.a	3	16	19	n.a
Madagascar	1200	160	800	960	80
Malawi	290	16	4	20	7
Mali	340	100	60	160	47
Mauritania	39	3	20	23	59
Mozambique	2400	66	4	70	3
Niger	100	10	20	30	30
Nigeria	2000	50	800	850	43
Rwanda	44	0	15	15	34
Senegal	180	30	70	100	56
Sierra Leone	100	5	50	55	55
Somalia	87	40	40	80	92
Sudan	3300	1700	50	1750	53
Swaziland	7	55	5	60	>100
Tanzania	2300	25	115	140	6
Togo	86	3	10	13	15
Uganda	410	9	3	12	3
Zaire	4000	4	20	24	1
Zambia	3500	10	6	16	>1
Zimbabwe	280	127	3	130	46
TOTAL	33641	2638	2381	5019	14.9

Sources : Study team estimates of area developed; Irrigation potentials from FAO Land and Water Davelopment Division, 1985 (provisional estimates).

greater design flexibility based on current farming systems, greater prospects for diversifying into high value crops such as fruits, vegetables and flowers and, generally, a more acceptable integration of irrigation as part of the farming system. There is also a reduced reliance on large bodies of water, and more sustainable use of locally sourced ground and shallow water.

This paper will attempt to elaborate on these scenarios by addressing a number of key issues defining the environment in which small-scale farmers adopt low-cost irrigation

equipment and associated technology. The broader environment is addressed by taking a "new" political economy perspective on the overall status of agriculture and irrigation development in Africa. Associated with this new perspective are issues of land tenure and governance. Finally, the paper examines a number of key institutions serving small-scale irrigation: credit, extension and marketing, before discussing prospects for improving the enabling environment for small-scale irrigation.

The Political Economy of Food, Agriculture and Irrigation Development in East and Southern Africa

The chronic inability of smallholder farmers to have their economic interests articulated in the political process is cause for serious concern particularly in dual agrarian societies. The lack of political wisdom to give priority to agriculture, particularly in terms of commitment to the transformation of smallholder agriculture is the most serious post-independence error of judgement by African nations. It is in this context that we have to analyse and discuss the prospects for small-scale irrigation, and prospects for intensification and greater adoption of low-cost irrigation equipment. The 21st Century will see an increasing number of hungry and malnourished people and this has to be regarded by African nations as politically and socially unacceptable.

Issues of smallholder agricultural development in general, and food security in particular can no longer be divorced from issues of democracy, politics and governance. Food insecurity is directly related to the secondary role accorded to agriculture in general and smallholder agriculture in particular. This secondary role is mainly so in terms of public sector support and investment in rural areas. By taking a "new" political economy approach, the roles and interaction between various interest groups in society are evaluated, and the state machinery or government is considered a special interest group in its own right with no supposition that government necessarily always acts in the interest of the majority of its citizens!

The transformation of smallholder agriculture to a more science-based production system requires committed governance as well as a system of public sector organizations with the capacity to support and transform small-scale agriculture in terms of productivity and participation in the national economy.

The traditional competition between large-scale commercial agriculture on one hand, and smallholder agriculture on the other, continues to cloud food and agriculture policy and opportunities. Commercial farmers are better integrated with the national economy, with particular reference to factor and product markets. Development of institutions that serve agriculture are also historically better suited to meet the needs of large-scale agriculture. There is *prima facie* evidence that large-scale commercial farmers have the political and financial resources to acquire adequate support from agricultural organizations such as research, extension, credit and marketing. It is time, therefore, to ask hard questions about the public sector agricultural institutions and their ability to generate rapid technical change for smallholders in agricultural societies of East and Southern Africa. Governments and their constituent agricultural departments will therefore continue to have a limited impact on the livelihood of the rural poor, unless indigenous scientific and bureaucratic leadership becomes more demand driven, i.e., able to meet smallholders' needs.

The political economy of food insecurity

Southern African nations are facing severe problems of hunger, malnutrition, rural unemployment, land hunger, population explosion and rural migration to decaying urban centres. In spite of economic reforms, a recent World Bank study acknowledges that structural adjustment programmes in sub-Saharan Africa are not generating a sustainable supply response in agriculture, particularly from smallholders (Donovan, 1996). In some instances, the escalation of fertilizer prices, the demise of public sector credit systems for smallholders and reduction of marketing services have created new challenges for smallholders. In Malawi, Zimbabwe and South Africa, for instance, economic reforms are benefiting commercial farmers who are largely exporters. Commercial farmers are either creating new support institutions (Zimbabwe, Malawi) or simply biasing the public sector ones in their favour (South Africa). It follows, therefore, that enhancing the capacity of public sector institutions to spearhead more rapid agricultural transformation for smallholders is a matter for urgent attention. Moreover, the majority of Africans are still rural, and it follows that the focus should be on smallholders to ensure that the benefits of development are broadly distributed.

Structural adjustment programmes (SAPs) have been the dominant stimulus for policy change in the agriculture and food sector over the last decade. SAPs have had limited positive impacts on input and output markets and prices, particularly in those countries with a reasonable physical infrastructure. SAPs have also had an inadvertent devastating fiscal impact on some public sector institutions such as research, extension, education, credit and fertilizer distribution systems that serve small-scale irrigation farmers. As Africa approaches the year 2000, agriculturists are taking stock of the impact of SAPs, particularly in light of growing evidence that SAPs are not generating a sustainable supply response in agriculture, particularly from smallholders.

Another troubling issue is the observed differences in results of SAP policies in different countries. De Capitani and North (1994) hypothesize that the differential performance is caused by differences in institutional development in the various countries. The implication is that many institutions supporting small-scale irrigation will have to be reformed as a prerequisite for improved performance.

In summary, African governments have paid lip service to smallholder agriculture, generally continued to tax this sector or at least treat it as a service sector. At the same time the governments have been protecting the cheap food interests of the urban minority, who by some strange twist of African politics are more politically powerful than the rural majority. It can be argued that while economic growth is the ultimate lasting solution to poverty and hunger, this growth will take time to be achieved in East and Southern Africa. It follows, therefore, that in the foreseeable future, growth policies and strategies have to be balanced by other safety net measures and deliberate policies which are pro-poor, pro-women, pro-rural children, pro-environment, as well as pro-rural employment. Such policies are difficult to come by under present political circumstances where the ruling political parties and the economically powerful private sector are urban biased. We shall also see later that small-scale irrigation is indeed pro-poor and pro-women and therefore, that African governments should invest more in this sector.

Getting agriculture moving

Since the majority of Africans are rural inhabitants and will continue to be so for some time to come, it follows that smallholder agricultural growth has to accelerate not only to address hunger, but also in part as an engine for generating the rural linkages for overall economic growth. Investing in rural areas becomes essential not only in infrastructure such as small-scale irrigation, but also in human resources, technology systems and effective public and private sector farmer support institutions. There is *prima facie* evidence, however, that the key agricultural organizations: research, extension, training, finance, marketing, land reforms etc. are currently not functioning in most African countries. Agricultural institutions have not forged a common vision or agenda to assist smallholders. It is vision and values that help organizations set priorities and strategies for action. Farmer support institutions generally enjoy limited patronage and partisan support of farmers and Ministries of Finance. The donor supported structural adjustment programmes have also inadvertently contributed to the weakening of these institutions through blanket policies of budgetary austerity. Part of the answer to this puzzle should be through an understanding of the agricultural policy which does not empower smallholders to have a voice in the search for opportunities and solutions to their problems.

If agricultural institutions are not guided by the needs of the rural majority, then it follows that individual agricultural institutions must have increased incentives to be creative and responsive and to interact and function as a system. Agricultural service organizations have the challenge to examine their operational inter-institutional relationships, and public servants do not appear to have incentives for collaborative action.

Farmer organizations representing smallholders as well as water users' associations are generally unable to institutionalize collective action on a special interest basis. The balkanization of smallholders, with limited capacity for collective action has created a political and institutional vacuum in rural areas of Africa.

Existing bodies of theory do not offer much in terms of a knowledge base on the development of institutions that induce development (North, 1990). Yet it is now crucial to understand why stagnation has persisted in Africa. What can be learnt from more successful political/economic systems which seem to have evolved flexible institutional structures that can survive the shocks and changes that are a necessary part of successful evolution?

LAND TENURE, GOVERNANCE AND SUSTAINABLE IRRIGATION DEVELOPMENT

The recent donor country pressure for African nations to adopt multiparty politics as the means to democracy has had its positive results. On the negative side, the rural majority are still peripheral to this process which, quite frankly, is rather alien to rural processes of democracy and transparency. The greatest need in rural areas seems to be the strengthening and development of rural communities and institutions into self-contained sustainable entities of society. Rural communities, even in the modern setting, still operate on principles of customary law or belief system and tradition still provides guidelines to legal and administrative processes outside government. These processes determine on one hand, the property rights regime including land tenure. On the other hand, this process has developed into an effective social security system that, from time immemorial, has allowed village people to look after the hungry, the poor, the old and the destitute without building separate

structures such as orphanages, old people's homes or soup kitchens. The greater the pressure that comes to bear on rural communities and traditional institutions, the less able these communities are to deal with social problems of poverty and food insecurity. An understanding of African traditional land tenure systems and the management of common property are essential elements in designing successful smallholder irrigation systems.

The land tenure situation in most smallholder farming areas of Southern Africa is so insecure and fluid that influential politicians and bureaucrats wield considerable power and influence on land issues. The fact that this traditional land is still viewed as state land has allowed political interference in its management, administration and legal interpretation of rights over the land and the water that flows on that land. It can be argued, therefore, that land tenure reforms which give traditional land users both communal and individual *de jure* ownership rights, are essential in creating effective and democratic rural and irrigating communities. These communities are able to exercise choice, be innovative enough in protecting their property rights and safeguard their economic interests.

Corporative type of governments ought to negotiate and develop partnerships with these communities, to establish agriculture and irrigation policies and programmes for a sustainable future.

The transformation of agrarian systems into urban-industrial economies invariably requires fundamental changes in many institutions, including those of land tenure (Dorner, 1992). The distribution of landownership is a major factor that influences this transition from one form of social and political order to another. Moore (1996), quoted in Dorner (1992), sums up the experience of all industrializing countries in the separation of a substantial segment of the ruling classes from direct ties to the land. Peter Dorner in this classic entitled "Latin American Land Reforms Theory and Practice, A Retrospective Analysis" refers to the Asian experience in relation to Latin America. He cites the land reforms in Taiwan and South Korea as having occurred early in their growth and industrialization process and that the industrial sector was never as closely tied to the egalitarian rural structures as is often the case in Latin America.

The African legacy can also be summed up in the lack of political wisdom or vision in terms of public policies, particularly for agriculture and natural resource management. Erratic rural economic growth is today translated into pervasive poverty, hunger, unemployment and environmental decline. It is now widely accepted that rural economic development is ultimately dependent on building strong and effective rural institutions and empowered communities. Issues of agriculture and natural resource management, therefore, can no longer be separated from issues of politics, democracy and good governance. These issues are based on growing evidence that agricultural growth and efficient management of natural resources are dependent on the political, legal, and administrative capabilities of rural communities to determine their own future and to protect their natural resources and other economic interests. The lack of this power (or lack of democracy) is translated into insecure tenure rights, abuse of common property and resources, disenfranchisement of rural people, particularly women and the breakdown or weakening of rural economic institutions.

Land reforms and land tenure reforms are infamous in Latin America for their limited success, while such needed reforms are conspicuously absent in Africa. Where land distribution is highly inequitable, arguments against land reforms are basically ideological and private property is assigned near-sacred rights. Private property is then elevated to the status

of the foundation of civilized society. But, as Dorner (1992) argues, if this premise holds, then it must likewise be accepted that private property cannot perform this noble function if most people are without it.

Land tenure, land reform and security of tenure

Land tenure institutions are invariably unique and develop out of historical patterns of settlement and conquest. Moreover, land tenure institutions are rooted in value systems and grounded in religious, social, political and cultural antecedents. Consequently, it is not always prudent to disrupt existing tenure systems in the process of developing irrigation systems.

The nexus between tenure and governance is found in the colonial and post-colonial belief that indigenous or traditional tenure systems are incompatible with western or 'modern' systems of government and its associated economic institutions. To examine the foregoing question and its implications, the concept of tenure security will be discussed first and then the various tenure systems and their possible evolution will be described.

It may, however, add clarity by differentiating between land reform and land tenure reform. Land reform encompasses change which redistributes land. Since land is a finite resource, its ownership is generally symbolic of wealth, social status and prestige which are the very basic elements or ingredients of politics. Land reform, by contrast, is a revolutionary process and passes power, property and status from one societal group to another. Land tenure reform usually involves changes in the rules that govern land and related property rights. Hence the close association between land reform and land tenure reform.

The literature on tenure emphasizes the need for tenure security and that the various types of tenure (including the "registered title") can be secure or insecure depending on social, legal and administrative institutions in a given society. Security of tenure is associated with four sets of rights. The basket of rights therefore indicates the relative security of a tenure system depending on secured rights from the four sets as follows:

- **user rights** are rights to grow crops, trees, make permanent improvement, harvest trees and fruits, and so on;
- **transfer rights** are rights to transfer land or use rights, i.e. rights to sell, give, mortgage, lease, rent or bequeath;
- **exclusion rights** are rights by an individual, group or community to exclude others from the rights discussed above; and
- **enforcement rights** refer to the legal, institutional and administrative provisions to guarantee rights

The four major categories of property rights define uses that are legitimately viewed as exclusive and also define who has these exclusive rights (Feder and Feeny, 1991). Rights may also have a temporal dimension. In parts of Africa and South Asia, for instance (as was the case in medieval England) rights to the crop are private whereas rights to the stubble after harvesting are communal. In parts of Africa, land and tree tenure are separate. In addition, rights may specify conditions affecting types of rights transfer and parties to whom such transfers may be effected.

Institutional arrangements include instruments for defining and enforcing property rights (be they formal procedures, social customs, beliefs or attitudes), determining legitimacy and recognition of these rights (Taylor, 1988). Enforcement often requires a buttress of instruments such as courts, police, financial institutions, the legal profession, land surveys, cadastral and record keeping systems, and tabling agencies.

Tenure systems can be categorized on the basis of those who enjoy exclusive rights. On this basis all tenure systems fall into four broad categories: open access, communal, private and state (Table 2). For practical purposes, there a few areas left in most countries that are truly open access. As a general observation, some land may appear or be treated as open access but such land is usually state land or communal land. When the state or community lack adequate legal and enforcement capacity, or when such capacity comes under pressure, the resultant insecurity of tenure is evidenced through land use patterns that mimic open access systems.

TABLE 2
Categories of land tenure systems

Category	Ownership of exclusive rights
Open access	None
Communal	Defined group
Private	Individual legal entity
State	Public sector

Exclusivity (of individual or group) therefore defines the degree of tenure security. Under communal tenure, exclusive rights are assigned to a group. Individual or family rights are also assigned under most traditional tenure systems. This explains why Migot-Adholla *et al.* (1991) argued that indigenous African land rights systems have been incorrectly represented by most foreign anthropologists, colonial administrators and some nationalist ideologues who view these systems as static polar contrasts to Western property rights system.

Private property rights are the most prevalent form of tenure in industrialized western countries. As alluded to earlier, however, private land rights are not God-given or sacred rights, but rather that private property is a creation of the state. After all, private property is not and cannot be an absolute right (Dorner, 1992, page 10):

> "It is not very helpful nor is it accurate, to say that private property and enterprise made the United States great and that this is what the United States has to offer in the struggle for economic development around the World. In fact, it is our open and flexible political system that has allowed us to make private enterprises *within the United States* consistent with the general public interest, as Marx thought it would never be. However, there is no reason to expect that private enterprise will automatically function in the public interest in a system lacking political institutions and the middle-class society in which they rest."

We will discuss later the fact that where private property rights are not viewed as legitimate, or not generally viewed as working in the public interest, or where they are simply not enforced adequately, *de jure* private property becomes *de facto* open access.

The Kenyan, and to some degree the Zimbabwean experience, with state-imposed change from traditional to registered title, have experienced problems based on the fundamental interpretation of these rights under customary law or belief. Often, traditional inheritance and succession laws will supersede the implied statutory laws of intestate inheritance. Moreover, in most matrilineal African societies, registered title usually means the

individual name of the male head of household appearing on the title. Since such title is negotiable property, women and dependent children are often prejudiced when property is let or foreclosed on business in which they were not involved. Under most African customary laws, the male may be head of family but the land is property belonging to the whole family. Wives and dependent children, therefore, should have inalienable rights to sub-division or inheritance. As a minimum therefore, the immediate family has to be party to or concede to any land transactions or mutations that may affect their immediate and/or future rights or interests. The cultural laws and practices of family rather than individual rights are the basis of Africa's celebrated social security system; a system that is still relatively cost-effective and unlikely to be replaced by state social security system for quite some time into the future.

State land is often used by the public sector but, more importantly for our discussion, most land under *de facto* indigenous or customary tenure, is usually *de jure* designated as state land. This situation poses the most serious source of tenure insecurity or lack of exclusivity.

Institutions, or rules of the game and how the rules are applied, are most important in determining how secure rights are and this goes for all tenure systems. Ultimately, and in the abstract, there is no tenure system that is good or bad, right or wrong, rather, any tenure system has to be secure, appropriate and able to facilitate the needs of a community or society.

Governance issues and implications for water rights

The majority of Africans hold their land under indigenous customary land tenure systems irrespective of the formal legal position under national law (Bruce *et al.*, 1993). This applies to most irrigated land under smallholder cultivation. Most African governments, however, designate traditional land as state land. Most governments accept the *de facto* prevalence of customary tenure, while at the same time maintain the *de jure* state ownership, which it turn allows bureaucrats, politicians and influential people to exercise privilege and authority over traditional land and rural communities.

Most smallholder irrigation systems, therefore, are controlled and managed by state organs. Some governments have attempted to replace customary tenure with state guaranteed individual rights (registered titles). The general experience, however, has been that state imposed individualized tenurial systems do not necessarily offer greater security for African land users, because of weaknesses of government institutions in Africa.

Communal tenure and common property management

African tenure systems have erroneously been explained through the notion of "tragedy of the commons". Observers believed that these systems of tenure assign land rights to the community and ultimately land users would not risk long term investment into improving the land and land based resources. More careful analysis of traditional tenure systems, however, shows that this tenure is composite, with clear freehold rights usually for arable and residential land, as well as group rights for pastures, forests, mountain areas, waterways, sacred areas and so on. The robustness of the tenure system, however, is dependent on the strength of the traditional institution in place, and degree to which state and other local government institutions interfere or supersede traditional rights and administrative process.

Most African governments, after political independence from colonial masters, have maintained the colonial legacy of inadvertent undermining of indigenous tenure systems. This undermining has occurred through two major approaches. Most prevalent is the practice that all land with no registered title is, *ipso facto*, state land. The second approach is the attempt to replace customary land tenure with state-imposed individual property rights to land and the land based resources. This change, it is assumed, is more compatible with the intensification and commercialization of agriculture.

There is mounting evidence, however, that land titling and registration programmes have generally not yielded positive benefits. Moreover, formal title did not necessarily mean an increase in tenure security (Roth *et al.*, 1989).

There is also growing evidence that indigenous tenure systems are dynamic and evolve with changing social, economic and political circumstances. Boserup (1981) and Feder and Noronha 1987 provide evidence corroborated by Bruce *et al.* (1993) that customary tenure rights evolve towards more alienable individual rights as population pressure increases and as agriculture becomes more commercialized.

Legal and administrative processes and water rights

A fundamental problem is the clash between customary laws governing tenure, *vis-a-vis* statutory laws which often are based on European or North American legal principles. A general observation is that customary laws tend to confer greater recognition to group rights, whereas western laws emphasize individual rights. These differences also lead to further differences in other elements of property rights institutions such as inclusion, exclusion, succession and inheritance. Water rights under traditional customary law is common property, managed for the greater good of the community. Most state laws, however, assign water rights to commercial (title deed) land, while the state enjoys water rights over traditional land. Smallholder irrigation, therefore, generally enjoys water rights via a third party, usually a state bureaucrat holding such rights in trust for the community. This situation exacerbates the already insecure land tenure situation and smallholder irrigators' rights are often susceptible to state and political interference.

Need to decentralize government and strengthen traditional institutions (including ability to resolve conflicts)

Highly centralized systems of government were judged as the most serious threat to tenure security for land users under all types of tenure in Zimbabwe (Rukuni, 1994). This problem is more serious for communally held land and state land occupied by communities under customary rights. Communities occupying such land have limited exclusivity of rights because state bureaucrats and related politicians also claim institutional authority over such land and in the worst of cases these state functionaries may be the *de facto* landlords. Ministries of Local Government in most African countries have responsibility for enforcing the state controlled system and often subordinate traditional institutions to the state bureaucracy. In some cases, Kenya for example, traditional leadership structures were dismantled after independence. To varying degrees, these traditional leadership structures have been weakened or disenfranchised after independence. The political justification for this disenfranchisement has been the historical association of traditional leaders with the colonial administration.

An illustrative case of decentralization and empowerment of local communities is the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) programme in Zimbabwe. CAMPFIRE is also under adoption in a few other Southern African countries. Under CAMPFIRE local communities manage and utilize their natural resources to their exclusive economic benefit. This approach has been most effective in the management of wildlife held on communal land. As a result of the financial incentives gained, these communities now take the initiative to protect and conserve the wildlife which in the past they would have poached. This experience confirms the need for greater empowerment of communities over the conservation of their environment. This is only possible through delegation of responsibility and authority and creating administrative and institutional mechanisms that are legitimate, effective and accountable in the control of land use and natural resource utilization. Rural communities, therefore, can own and utilize common property resources effectively and sustainably, provided they clearly benefit from the resources and they (the communities) are empowered through local level institutions. This concept needs to be extended to the use and management of water resources by irrigating communities.

Land tenure and economic efficiency

A growing body of research based knowledge on tenure demonstrates that the most important characteristic of tenure security under indigenous systems is the ability to bequeath land. Pace *et al.* (1993) examined studies by the World Bank and the Land Tenure Center and they also studied a number of African countries to derive a comparative analysis of Burkina Faso, Ghana, Rwanda, Kenya, Senegal, Somalia and Uganda. This analysis confirmed that indigenous systems do not hinder productivity or investment. In addition, land registration has not necessarily led to tenure security. Government intervention, therefore, makes sense only after establishing causes of tenure insecurity, and also bottle-necks to rural development. As productivity of land and natural resources increases, agriculture becomes more commercialized and as population densities increase then appropriate registration efforts bear positive results. The same may apply where land grabbing by powerful elites is unchecked. Recent research also demonstrates that the high productivity increases enjoyed by smallholders in Kenya and Zimbabwe had and still have less to do with individual tenure. Rather, the removal of prohibitions and other bottlenecks for smallholders were more important than land tenure changes.

Research has also exposed two other economic fallacies associated with state imposed individual tenure reforms. First is the fallacy of economies of scale in agricultural production. Worldwide evidence shows no real scale economies, and if anything, small farms can be as highly economically efficient as any sized farm. The second fallacy is the traditional state view that multiple parcels of land in separate locations are inefficient for production. Once again evidence is showing that there is great wisdom in smallholders having multiple parcels of varying potential and/or suitability for a wide spectrum of crops grown. These two fallacies lead governments into pursuing policies for consolidating holdings and policies against sub-division of land. This policy has also been a drawback for smallholder irrigation as most governments discourage irrigators from cultivating several parcels of land. Often, smallholder irrigators are discouraged or prohibited from rainfed agriculture or other non-irrigation activities. These policies are not based on established fact, and often hinder the economic strengths of traditional practices.

Land tenure, in summary, is a complex issue which should be allowed to develop or evolve with changing socio-economic and cultural conditions of a given community. Traditional or customary tenure systems offer as much security as any other system provided that communities have legal ownership and authority over their land and irrigation system. Governments can strengthen this tenure system by supporting and empowering local communities. Highly centralized systems of governance, combined with bureaucratic topdown decision making tend to impose decisions on people at the grassroots level. This system of government is weak in terms of effectiveness, impact, accountability and transparency and it denies people the chance to be self-innovative. Governments have to fully understand traditional and indigenous tenure systems before radical attempts are made to alter them for ideological or purely political reasons. These tenure systems have survived a century of neglect, abuse and exploitation by colonial and contemporary governments. Above all, these tenure systems require support to strengthen local institutions and empower local communities in administering tenure and allowing the tenure system to evolve over time. Tenure security in terms of exclusive rights of groups and individuals it has hopefully been argued, are the very basis of political and social power and status. When such rights are overly subordinated to the state, it follows that the political rights of rural people are diminished and that democratic processes and institutions are undermined. This diminution of rights and undermining of democracy is a major cause of tenure insecurity, with resultant negative impact on agricultural productivity and the management of natural resources, particularly on communally held land and irrigation systems.

Economics of Small-Scale Irrigation

The intensification of small-scale irrigation is now, in my judgement, one of the most important tools that Africans should give priority to over the next few decades. The majority of holdings in Africa are small, often ranging between 1-3 ha. But there is nothing economically amiss with small holdings. In fact, there is ample international evidence that small holdings are often more productive that larger units, i.e. in terms of yield per hectare and profit per hectare. It is with this realization that Fraenkel (1986) devoted a handbook on water pumping devices.

Fraenkel (1986) cites a number of studies to demonstrate that smallholdings generally achieve better energy ratios than larger ones i.e. the ratio of energy available in the crop produced, to the energy required to produce it. Smallholder family farms also offer greater impact on alleviating poverty, hunger and unemployment. In addition, smallholder farmers who use irrigation generally achieve much higher incomes than their rainfed counterparts. The difference in incomes range up to about 500% depending on the country.

This generally favorable economic disposition of small-scale irrigation will be examined in the context of East and Southern Africa. This discussion will hopefully, demonstrate that small-scale farms could use to greater advantage, low-cost equipment, particularly pumping devices for greater productivity and energy efficiency.

Financial profitability of small-scale irrigation

There is growing evidence from studies in East and Southern Africa that Small-Scale irrigation is generally financially viable. Ruigu and Rukuni (1990), Rukuni, Svendsen, Meinzen-Dick with Makombe (1994) and Ubels and Horst (1993) are some among the growing literature demonstrating the viability of small-scale irrigation.

TABLE 3
Gross margins, per hectare and per unit water, by holding size

	Summer			Winter		
	Gross margin per total ha	Gross margin per ha-m	Sample size	Gross margin per total ha	Gross margin per ha-m	Sample size
Agritex Systems	(Z$/ha)	(Z$/ha-m)	(holdings)	(Z$/ha)	(Z$/ha)	(holdings)
<0.25ha	831 (1338)	980 (1901)	40	3119 (2351)	2430 (1604)	14
0.25 - 0.49 ha	1045 (992)	1109 (1206)	42	1595 (1929)	1684 (2410)	26
0.50 - 0.99 ha	679 (688)	767 (805)	51	1143 (813)	1520 (1162)	35
1.00 - 1.49 ha	475 (520)	387 (453)	18	268 (350)	409 (519)	9
1.50 - 1.99 ha	97 (328)	59 (256)	11	633 (610)	361 (358)	8
2.00 - 5.00 ha	369 (377)	351 (365)	4	241 (110)	922 (619)	4
Community Systems						
<0.25 ha	916 (1988)	821 (2225)	58	1897 (1965)	2239 (1830)	28
0.25 - 0.49 ha	267 (391)	345 (550)	16	1490 (1627)	1482 (1626)	16
0.50 - 0.99 ha	98 (276)	29 (439)	10	333 (190)	392 (661)	5
1.00 - 1.49 ha	304	692	4	492	398	5
1.50 - 1.99 ha	519 (0)	1046 (0)	1	n.a. -	n.a. -	0
2.00 - 5.00 ha	342 (0)	493 (0)	1	887 (0)	2524 (3)	1
Garden Systems						
<0.25 ha	3097 (2921)	1868 (1517)	37	2582 (2576)	3395 (2631)	20
0.25 - 0.49 ha	1774	1242	15	1417	3452	12
0.50 - 0.99 ha	2022 (1502)	1165 (759)	12	947 (990)	1522 (1567)	9
1.00 - 1.45 ha	1969	1669	3	159	365	3

Source: UZ/IFPRI/Agritex survey date, 1990/91. n.a. not available; - not applicable

This section draws heavily on evidence from Zimbabwe to demonstrate the economic viability of small-scale irrigation in spite of low levels of capital investment. Table 3 shows that the garden and community systems out-perform the government (Agritex system) in terms of financial return per hectare. Community owned schemes also perform better than government schemes in terms of participation in marketing and savings clubs (Table 4). Table 5 shows the range of the low-cost equipment owned and used on smallholder systems. It is clear that farmers are not investing in low-cost pumps and this therefore is an area that needs to be addressed, particularly for garden (bani) systems.

Moving beyond Zimbabwe, Tables 6 and 7 show respectable financial rates of return to capital in a range of African countries. Table 8 shows a negative return to large systems, particularly in Bura, Kenya.

Institutions Supporting Small-Scale Irrigation

The lack of effectiveness of the national system of agricultural institutions in terms of support to smallholder irrigation is a major issue. There is *prima facie* evidence that key agricultural institutions of research, extension, rural finance and marketing are not functioning as an

integrated system in most countries in the region. These institutions have not forged a common vision or agenda to assist smallholder irrigators. Public servants, in general, and their careers in particular, are unaffected by how smallholder farmers view their performance. This sad state of affairs is worsened by the top-down center-periphery, linear and sequential view of scientific and institutional processes that obscure the participation of smallholders (Antholt, 1994).

TABLE 4
Farmer organizational participation at sample irrigation schamas 1990/91 (percent)

Scheme	Marketing cooperative	Savings clubs	Labour group
Community	24	12	34
Bangure	15	10	55
Chakandura	45	30	55
Mkoba	30	13	39
Mutambara	16	6	19
Agritex	12	4	12
Mabodza	30	13	22
Mondi Mataga	15	15	15
Mwerahari/Sachipiri	21	26	5
Senkwazi	25	10	30
Chakohwa	14	0	0
Chibuwe	6	3	3
Tawona	9	0	24
ARDA	8	0	0
Middle Sabi	27	0	0
Chisumbanje	0	0	13
Bani	22	5	17
Maboleni	21	11	26
Dufuya	21	4	14
Mbiru	19	6	19
Mushimbo	33	0	25
Dryland	29	31	30
Charandura	55	40	60
Chakohwa	0	22	0

Source: UZ/IFPRI/Agritex Survey Data, 1990/91.

Rural finance

Problems of transaction costs and collateral feature prominently in explaining the failure of smallholder credit schemes in Africa (Mabeza-Chimedza, unpublished). According to Mabeza-Chimedza, the failure of public schemes, in spite of concessional interest rates resulted from the limited lending experience of these organizations, the high transaction costs, and the lack of collateral by target farmers.

These are all problems faced by smallholder irrigators as well. Most recent efforts with micro-finance are aimed at reducing transaction costs. These efforts are also floundering because of the focus on the supply side of finance while neglecting the demand side. By neglecting the demand side, Mabeza-Chimedza concludes, solutions to the problem of high transaction costs have only managed to shift costs from supply to the demand side without actually reducing them.

Zimbabwe's experience with the National Farm Irrigation Fund (NFIF) is a typical example of the failure of public sector credit schemes targeted at small-scale irrigators. The NFIF was established in 1985 with a start-up capital of Z$18 million for a revolving fund available to both small and large scale irrigators. To date, however, most of these funds have been utilized by large farmers whilst a negligible amount has been invested in expanding small-scale irrigation.

The first complication with the NFIF was the requirement that funds be utilized for in-field works only for smallholders. But because communal or traditional land is *de jure* state land, this means that farmers cannot borrow these funds against the land that is to be developed. The state (land owner) would have to finance this operation. In addition, these farmers do not have water rights since these rights also belong to the state. In contrast, large farmers with titled land can acquire water rights in their own right.

TABLE 5
Working capital on sample irrigation system 1990-91

	Percentage of farmers owning											
	Farm equipment					Irrigation equipment			Transport equipment			
	Plough	Harrow	Cultivator	Planter	Ridger	Sprayer	Tractor	Siphon	Wheel barrow	Scotch Cart	Bicycle	Vehicle
Community	84	58	44	6	4	26	0	44	68	57	48	7
Bangure	90	45	10	0	10	0	0	90	85	75	50	5
Charandura	100	85	75	10	15	10	0	60	100	85	75	10
Mkoba	87	74	52	13	0	26	0	96	70	70	70	13
Mutambara	76	46	39	3	3	39	0	3	52	36	27	3
Agritex	87	66	47	11	8	44	0	50	68	62	53	8
Mobodza	96	83	87	9	4	35	0	96	78	87	83	13
Mondi Mataga	100	46	92	8	0	46	0	15	85	92	46	15
Mwerahari/Sachipiri	95	79	63	0	5	5	0	32	74	79	83	0
Sankwazi	75	40	50	5	0	35	0	85	60	60	60	0
Chakohwa	86	61	54	0	14	36	0	89	89	61	32	18
Chibuwe	89	51	26	23	3	31	0	23	50	57	54	3
Tawona	83	74	47	6	6	71	50	44	74	58	50	6
ARDA	50	17	42	0	11	91	0	75	79	60	91	16
Middle Sabi	0	0	13	0	0	67	100	13	93	7	85	47
Chisumbanje	69	23	54	0	15	100	0	100	73	81	92	4
Bani	92	39	34	6	0	3	0	8	39	46	29	2
Maboleni	93	54	50	7	0	11	0	0	46	68	54	0
Dufuya	96	43	36	7	0	4	0	11	29	50	29	4
Mbiru	75	25	19	0	0	0	0	0	75	25	25	0
Mushimbo	92	17	42	0	0	0	0	8	25	33	8	0
Dryland	88	25	23	3	0	3	0	0	65	48	38	5
Charandura	95	50	40	5	0	0	0	0	85	70	40	5
Chakohwa	80	0	5	0	0	5	0	0	45	25	357	5

Source: UZ/IFPRI/Agritex Survey Data, 1990/915

TABLE 6
Cost per hectare of irrigation development in selected SADC countries, 1985

	Botswana US$/ha	Zambia US$/ha	Zimbabwe US$/ha
All projects analysed	5 886	2 032	9 460
Projects with:			
IRR 20% or larger	916	1 840	3 957
IRR 10-20%	4 869	2 640	9 908
IRR below 10%	11 964	8 808	9 483
Area analysed (10 ha)	35	13	63
Percent of potential	60	3	14

Note: IRR = Internal Rate of Return Exchange Rates per US$ are Pu2; Zk 11 and Z$1.59.
Source: Olivares (1987)

TABLE 7
Comparison of basic data on irrigation projects from a few selected countries south of the Sahara

COUNTRY Name of Project and Closing Date	Cost of Irrigation Works (US$M)	Bank/ IDA Lending (US$M)	Total Project Cost (US$M)	Implement Expected (in years)	Period Actual (in years)	ERR Expected (%)	ERR Expected (%)
BURKINA FASO Second Rural Development	6.04	9.4	18.5	7	7	16	1
CAMEROON							
Semry Rice I (6/76)	3.55	3.7	9.3	4	4	13	23
Semry Rice II (9/84)	21.6	29.0	55.5	6	6	15	20
KENYA							
Bura Irrigation (6/86)	16.0	40.0	105.0	6	8	13	-
MADAGASCAR							
Lake Alaotra Irrigation (6/75) Morondava	5.18	5.2	8.96	5.5	4.5	11	22 1/ 2/
Irrigation (12/88)	n.a.	14.1	56.6	5	8.5	16	3/
MALI							
Mopti Rice 1 (11/78)	5.62	9.5	13.1	6	6.4	14	17
Mopti Rice II (6/2)	16.2	14.8	31.5	5	7	18	3
MAURITANIA							
Gorgol - Noir Irrigation (3/82)	45.2	15.0	24.5	4	4.6	12.5	3
NIGER							
Irrigation I (6/84)	18.4	15.0	24.5	4	4.6	12.5	3
NIGERIA							
Agriculture Rice Deve 1	24.3	16.3	46.6	5	6	17.6	*
Bida Agriculture Deve. (6/86)	8.2	23.0	64.4	8	7	16	19.3
SENEGAL							
Debi-Lampsar Irrigation (3/86)	22.62	20.0	36.7	5	8	10	-4
SOMALIA							
NW Agriculture (6/86)	8.69	10.5	14.9	6.5	7.5	11	-2
SUDAN							
Rahad Irrigation (12/82)	164.6	15.6	395.6	6	7.5	15	20

Negative 1/1977 2/1981 3/negative to zero

TABLE 8

Estimated ERR of some irrigation projects in sub-Saharan Africa

COUNTRY IRRIGATION PROJECTOR (%)		
Madagascar	Lake Alaotra	Negative
Sudan	Rahad	20.0
Mauritania	Gorgol Noir	2.7
Kenya	Burra (settlement)	-13.0
Niger	Niger	3.0
Burkina Faso	Nina Dionkele (rice)	-5.3
Cameroon	Secondary Semry (rice)	16.0
Senegal	Polders	-
Sudan	Rosires	14.0

Research and extension

It appears that problems with research and extension systems are likely to a be 'long haul' rather than a 'quick fix'. The vision and commitment for that change has to come from within each African nation. It could be argued that the stage is set for this change to happen given the impressive growth in numbers of well qualified scientists in agriculture R&D organizations, but it would appear that public sector research organizations are largely out of synch with their most important client, the smallholder farmer. Research and extension services are poorly linked, and these institutions are facing severe budgetary cuts.

The ideological shift from public agricultural organizations to entrepreneurial agencies able to exploit economic and political opportunities for their clients is most urgent. Institutional innovation, however, has not been handled as a social and researchable issue. Social scientists have tended to concentrate on "safe" issues such as marketing, farming systems research and participatory rural appraisals whilst avoiding the major issues. Social scientists also tend to avoid controversial issues, yet it tends to be the controversial issues that have a higher pay-off in terms of change (Busch and Lacy, 1983).

Some institutional problems experienced by African countries can be traced back to inherited colonial institutions (Dumont, 1996). Southern African countries have inherited mainly British colonial institutions, administrative structures and education systems. Dumont argues that even in the face of retarded national development and ineffective institutions, bureaucrats will proceed on this pathway as long as they can hang on to some privileged status.

With particular reference to irrigation, Africa has invested minimally in research and extension or low-cost irrigation equipment, yet these areas should achieve great returns if successful. Poor links with the private sector also means that not much is happening in developing prototypes for manufacture, or importation of units for tests and possible mass production.

Marketing and trade

The marketing and trade of irrigated high-value crops offers the greatest opportunity for intensifying small-scale irrigation in East and Southern Africa. The Uruguay Round, leading to the World Trade Organization and the agreement on agriculture now suggest that food and agricultural markets are increasingly being deregulated and freed from state intervention. Africa now has to recapture its diminishing share of the world agricultural markets. Table 9 shows the clear trend in this loss of markets for high value crops.

This section draws heavily from several articles contained in the volume edited by Jaffee and Morton (1995), on Marketing of Africa's High Value Foods. Table 10 shows that among high value foods, Africa'exports are largest for fresh fruit and vegetables (especially citrus fruit, pineapples and bananas), which are all suited to small-scale irrigation. Gaffee (1995)

summarizes in Table 11 the economic properties of major marketing infrastructure and the functions necessary for successful marketing of high value commodities.

Most private traders and processors in Africa face considerable infrastructural constraints, endure substantial risks, and incur considerable costs because of inadequate and dilapidated transport and communications infrastructure (Jaffee and Morton, 1995). Table 12 shows how Africa lags behind its Asian counterparts with respect to physical infrastructure. African countries have far lower rail and road densities, fewer motorized vehicles, poorer access to telephone and postal services, less rural electrification and fewer international air freight traffic. All these factors hinder greater intensification of smallholder irrigation and marketing of high value and/or perishable commodities.

Fresh fruit, vegetables and cut flowers still offer one major growth area for the future in East and Southern Africa. Table 13 shows that between 1976 and 1989, Sub-Saharan Africa's horticultural exports grew from US$ 636 million to more than US$15 billion. This appears to be a major growth area for the future. Table 14 also shows a weighted increase in Africa's world market share of horticultural products between 1973 and 1989. This increase was largely due to relative increments in the market share for fresh fruit and nuts, as well as cut flowers.

TABLE 9

World market shares of sub-Saharan Africa for major agricultural commodities (% of world export value)

Commodity	1969-71	1989-91
Coffee	27.3	17.8
Cocoa	77.9	67.1
Sugar	16.0	13.9
Tobacco	8.6	8.6
Tea	7.7	13.5
Combined	15.5	15.3
	20.8	16.3

Source: Data from FAO *Trade Yearbook*, various issues

TABLE 10

African exports of high value food products (1988)

Product group	Export value ($Million)	% of HVF exports
Fruit/Vegetables	1217.0	41.6
Fresh	930.6	
Processed	286.6	
Fish Products	957.0	32.7
Shell Fish	481.2	
Other	475.8	
Livestock	313.2	10.7
Live Animals	163.7	
Meat	138.0	
Diary	11.5	
Oilseed/Oils	270.3	9.2
Oilseeds	112.3	
Oils	158.0	
Nuts/Spices	165.0	5.6
Nuts	58.8	
Spices	108.4	
Totals	2922.5	100.0
Items:		
Total African Food Exports	8180.6	
Coffee Exports	2436.3	
Cocoa Exports	1883.5	

Source : TARS Data Base (World Bank)

Conclusions and Implications for Donors

This paper has demonstrated and argued that the future of irrigation in Eastern and Southern Africa is in smallholder production, marketing and export of high value commodities, particularly fresh fruit, vegetables and cut flowers. Policies have to shift from large to small-scale and designs have to emphasize small, owner-operated systems. With opportunities in tube-wells and shallow groundwater, smallholder irrigation will benefit tremendously from a greater abundance and choice of low-cost pumping devices.

TABLE 11
Economic properties of infrastructure and functions associated with food marketing

Facilities/function	Public good properties	Externality	Economics of scale/scope	Moral hazard
Overhead Infrastructure				
Roads	X	X		
Rail and Port Facilities		X	Large	
Marketplaces		X	Some	
Power and Water Services		X	Large	
Production Support Services				
Inputs Supply		X	Some	X
Production Finance				X
Technical Info Supply	X	X		X
Market Info Supply	X			X
Post-Harvest Assessment/Transformation				
Crop/Production Intelligence			Some	
Initiel Grading/Selection		X		X
Product Assembly				
Storege			Some	
Quality Control		X		X
Processing			Veried	
Marketing end Distribution				
Locel/Internationel Transport			Some/Large	
Wholesaling/Reteiling			some	
Merket Reseerch/Intelligence			Some	
Product Promotion			Some	X
Standardization			Some	
Country/Industry Promotion	X		Some	

TABLE 12
Comperetive indicators of infrastructure development end access

Country	Rail and road mileage per 100 persona (1989/90)	# of motorized vehicles per mile of paved road (1989/90)	# of telephone main lines per 1000 persons (1991)	Average no. of people served by one post office (1986-88)	Percent of villages with electricity	Int'l scheduled aircraft departures (000s) (1991)	Intl freight loaded + unloaded (000 tons) (1989/90)
Cameroon	Na.	Na.	3.16	33 800	Na.	3	13 7
Cote d'Ivoire	Na.	Na.	5.35	8 600	Na	2	29 7
Kenya	0 30	19.2	7.37	20 900	3	5	54 2
Nigeria	0.73	23.7	2.65	28 400	Na	6	30 0
Senegal	0.44	12 2	6.05	Na.	4	2	Na
Tanzania	0.15	14 2	2.80	30 300	Na.	3	5.6
Zimbabwe	1.09	35/7	13.70	24 300	5	3	Na.
Bangladesh	0.07	47/5	1.83	13 200	12	6	Na.
India	0.68	49 0	6.14	4 700	61	16	282.5
Indonesia	0.77	Na.	5.22	9 900	Na.	24	97.1
Pakistan	0.73	42.5	7.76	8 100	62	16	120.7
Philippines	1.65	51 8	10.87	Na.	52	9	Na.
Sri Lenka	1.01	Na.	7 13	4 300	Na	8	38.8

Na. Not availaable, Sources: Siemens (1992); Civil Aviation Statistics of the World (1991; International Road Trensport Union (1990); UNDP Human Development Report (1993); Ahmand and Donovan (1992).

TABLE 13

Expansion of sub-Saharan Africa's exports of horticultural products (US$ million; F.O.B. value)

Product category	1976	1980	1989
Fresh Fruit + Nuts	307.5	659.1	1 025.0
Processed Fruit	207.7	277.4	284.0
Fresh Vegetables	97.3	122.8	117.1
Preserved Vegetables	11.2	14.9	18.1
Cut Flowers	12.6	18.0	67.6
Totals	636.3	1 092.2	1.511.8

Source: Data from United Nations, *Yearbook of International Trade Statistics*, various years.

TABLE 14

Sub-Saharan Africa's world market share of horticultural product exports

Product category	1973	1989
Fresh Fruit + Nuts	5.4	6.2
Processed Fruit	12.6	4.2
Fresh Vegetables	3.1	0.9
Preserved Vegetables	0.6	0.5
Cut Flowers	1.0	3.0
Totals	4.3	3.6

Source: Based on data from United Nations, *Yearbook of International Trade Statistics*.

Six major implications have been isolated for donors, in particular, so that their support strengthens the prospects and viability of smallholder irrigation systems in the region. These are :

- **Emphasize small-scale, smallholder owner-operated systems:** Large donors move considerable sums of money and are often in a hurry to disburse. The tendency has therefore been to support the large and visible state supported systems. Donors need to focus on the smallholder systems (owner-operated or community owned). Such systems have greater impact on the poor, women, create more jobs and run at lower cost.

- **Community empowerment:** Most institutions essential for effective running of smallholder irrigation systems center around the community. Donors should empower the irrigation communities rather than the bureaucrats. Even in those cases where smallholders are on state run systems, donors should support the communities directly in their efforts to rehabilitate or operate the system. Donors, ultimately, should assist smallholders acquire the irrigation system from the state and assist the community to manage the system.

- **Reform and land tenure and property rights institutions:** Most African governments are slow in reforming land tenure systems and property rights institutions relating to natural resources particularly water. Reforms that strengthen tenure security and allow greater say by irrigators over the land and water that they use should yield greater investment and more efficient utilization of water and irrigation systems. Donors may not be able to interfere in land tenure reforms but could support related research and respond to community based efforts to strengthen the legal and institutional instruments of tenure and property rights regimes.

- **Research and testing of low-cost pumps:** Since pumping at low volumes with an individual unit offers the greatest opportunity for independence and innovativeness by farmers, donors should support such protracted testing and enter into agreements with the private sector for mass production and distribution of successful prototypes.

- **Promote local marketing and trade:** The lack of product and market information is one major drawback of successful penetration of high value markets by smallholder irrigators. Government extension services often do not have this knowledge. Donors could assist in this area. In addition, farmers and marketing cooperatives should value training on marketing strategies.

- **Micro-finance:** Owing to poor rural financial markets, there is need for donors to encourage the intensification of smallholder irrigation through support to miero-credit schemes. Such schemes must be community based and must encompass both saving and borrowing. By supporting the production, marketing and processing of high value commodities, micro-finance schemes could be the decisive factor for sustained adoption and sustainable use of low-cost irrigation equipment in East and Southern Africa.

REFERENCES

Antholt, C. 1994. Getting Ready for the Twenty-First Century: Technical Change and Institutional Modernisation in Agriculture. World Bank Technical Paper Number 217. The World Bank, Washington D.C.

Barghouti, S. and Le Moigne, G. 1990. Irrigation in Sub-Saharan Africa : The Development of Public and Private Systems. World Bank Technieal Paper No. 213. World Bank, Washington D.C.

Boserup, E. 1981. Population and Tcehnologieal Change. A Study of Long Term Trends. Chicago: University of Chicago Press.

Bruce, J.W., Mighot-Adholla, S.E. and Atherton, J. 1993. The findings and their policy implications: institutional adaptation on replacement. In: Bruce, J.W. and Migot-Adholla, S.E. Searching for Land Tenure Security in Africa. Dubugue. Kendall/Hung Publishing Company.

Brusch, L. and Lacy, W.B. 1983. Science, Agriculture, and the Politics of Researeh. Boulder: Westview Press.

De Capitani, A. and North D.C. 1994. Institutional Development in Third World Countries : The Role of the World Bank. Draft paper discussed at a Bank seminar Mareh 11.

Donovan, P.A. and Limwado, G.M. 1996. The Social Benefits of TRF's Research and Development on Tea in Malawi.

Dorner, P. 1992. Latin American Land Reforms in Theory and Praetice. Reforms in Theory and Practice. A Retrospective Analysis. Madison. The University of Wisconsin Press.

Dumont, R. 1966. False Start in Africa. New York: Praeger.

Feder, G. and Feeny, D. 1991. Land Tenure and Property Rights : Theory and Applications for Development Policy. The World Bank Economic Review 5:1, pp 135 - 154.

Fraenkel, P. 1986. Water Pumping Devices: A Handbook for Users and Choosers. London. Intermediate Technology Publications.

Jaffee, S. and Morton, J. (eds.). 1995. Marketing of Africa's High Value Foods. Comparative Experiences of an Emergency Private Sector. Dubuque. Kendall/Hunt Publishing Company.

Migot-Adholla, S.P. Hazell, B. Blorel and Place, F. 1991. Indigenous Land Rights in Sub-Saharan Africa: A Constraint on Productivity The World Bank Economic Review, 5.1. pp 155 - 175.

Moore, B. 1966. Social Orgin of Dictatorship and Democracy. Boston : Beacon Press.

North, D. 1990. Institutions, Institutional Change and Economic Performance. Cambridge: Cambridge University Press.

North, D. 1994. Economic performance through time. The American Economic Review 84(3): 359-368.

Pace, F., Roth, M. and Hazell, P. 1993. Land tenure security and agricultural performance in Africa: overview of research methodology. In: J.W. Bruce, S.E. Mighot-Adholla and J. Atherton. The Findings and their Policy Implications: Institutional Adaptation on Replacement in Bruce, J.W. and S. E. Migot-Adholla. 1993. Searching for Land Tenure Security in Africa. Dubugue. Kendall/Hung Publishing Company.

Roth, J., Barrows, R., Carter, M. and Kanel, D. 1989. Land ownership security and farm investment: comment. American Journal of Agricultural Economics 71: 211-214.

Ruigu, G.M. and Rukuni, M. (eds.). 1990. Irrigation Policy in Kenya and Zimbabwe. Proceedings of the Second Intermediate Seminar on Irrigation farming in Kenya and Zimbabwe, held at Juliasdale, Zimbabwe, 26-30 May 1987. IDS University of Nairobi. Kenya.

Rukuni, M. 1994. Report of the Commission of Inquiry into Appropriate Agricultural Land Tenure Systems. Vol. 1. Main Report; Vol. II. Technical Reports; Vol. II. Methods, Procedures, Itinerary and Appendices. Harare : Commission of Inquiry.

Taylor, J. 1988. The Elecal foundations of the market. In: V. Ostron, D. Feeny and H. Pichteds. Rethinking Institutional Analysis and Development: Issues Alternatives and Choices. San Francisco, Institute for Contemporary Studies Press.

Ubels, J. and Horst, I. (eds.) 1993. Irrigation Design in Africa. Towards an Interactive Method Wageningen Agricultural University, Wageningen, and Technical Centre for Rural and Agricultural Cooperation, Ede, The Netherlands.

Economics of irrigation technology transfer and adoption

Irrigation has helped to increase agricultural production in the last 30-40 years in developing countries and has evoked great expectations. Irrigated agriculture plays a very small role in African agricultural economies though irrigation is a technological option for agricultural development of the sub-Saharan Africa as in the tropics. Nearly 65 percent of all land in sub-Saharan Africa is arid/semi-arid, but less than 3% of the land (except two countries) is under irrigation. Rainfed agriculture is very important in sub-Saharan Africa, and is one of the reasons for fluctuations in agricultural production in these countries.

The contribution of irrigation in cereal production for food security is increasing, as rice is produced in an irrigated environment. Irrigation is particularly necessary in the dry season from May to November and consequently supplementary irrigation is needed in the wet season. This pattern of irrigation reduces the risk of food crop failure in the wet season and assures the utilization of the residual moisture in the dry (summer) season.

Fresh water availability in Malawi, Tanzania, Zimbabwe and Zambia is substantial and per caput availability per annum is about 1 000m^3 for Malawi, 2 300 m^3 for Zimbabwe, 3 000 m^3 for Tanzania and 11 800 m^3 for Zambia. Water withdrawal in these countries is less than 2%, except in Zimbabwe where it is about 5%. Therefore, there is great potential for irrigated agriculture as a means of achieving the food security goals.

However, irrigation equipment and methods currently used need to be improved. Many low-cost irrigation technologies for using water and for efficient pumping are available in the Asian countries like India, China and Malaysia. These technologies can be appropriately transferred to these African countries at a comparatively lower cost. This proposal provides the approach to transferring such low-cost irrigation technologies from the Asian countries.

The overall government policy in the countries under review is to promote social and economic development through sustainable irrigated agriculture. That approach must be economically justified, financially viable, socially acceptable and technically sound without causing unacceptable impact on the environment. It must also ensure that irrigation development programmes benefit as many households as possible and, in particular, those which belong to the most vulnerable groups of the rural community.

In light of the above, irrigation development, particularly small-scale irrigation, will be an important component of a diversification and expansion strategy to strengthen food security for the future. There is also a need to identify crops and irrigation techniques which will give higher returns to water and the overall investment. The best and most economical uses of water for irrigation are essential to any strategy of irrigation development.

K. Palanisami
Professor of Agricultural Economics
Tamil Nadu Agricultural University, Coimbatore, India

This paper which is mainly derived from the earlier mission reports in the four countries†- Tanzania, Malawi, Zambia and Zimbabwe - highlights the potential for irrigation technology transfer, economics of irrigation, national capacity in technology transfer, transfer of experiences in equipment manufacture, transfer of low-cost technology, assessment of suitability of irrigation technology in Africa, cost price considerations and potential for joint venture.

POTENTIAL FOR IRRIGATION TECHNOLOGY TRANSFER AND UPTAKE

Tanzania

River diversion schemes

Smallholders traditionally use water as a common property. Water is used according to customary laws of each area and proximity guides the rights to use water. Two main sources are common in the smallholder irrigation: (a) direct river diversion, where the gravity method of irrigation is practised, in regions such as Arusha, Iringa, Kigoma, Kilimanjaro, Lindi, Mara, Mbeya, Morogoro, Mtwara, Rukwa, Ruvuma and Tanga. This method accounts for about 60 percent of the total area under smallholder irrigation; (b) water harvesting, where flood waters from seasonal streams/rivers are captured and stored for future use, in regions like Dodoma, Tabora, Singida, Mwanza and Shinyanga. This source accounts for about 30 percent of the irrigated area.

Average size of irrigation plots varies from 0.1 to 0.5 ha with farmers owning two to three plots. The size and location of the plots are not uniform. In some of the rehabilitated schemes like Majengo, Lower Moshi, Ndungu and Mwamapuli, plots are consolidated and contiguous.

Shallow wells

Groundwater is extracted by open/dug wells or boreholes with a 12 to 20 cm diameter. Pumping accounts for a comparatively lesser proportion of the irrigated area as pumping groundwater for irrigation is very limited. Only about 480 ha are irrigated from lakes and about 200 ha from groundwater using both diesel and electric powered pumps. Hand pumps are used to irrigate vegetables in small plots in the towns. Municipal water is also used to irrigate kitchen gardens and vegetable plots.

Currently, only hand pumps for domestic water supply are manufactured locally by companies such as Tanira. The import and use of a particular type of equipment is also related to the donor country funding the rehabilitation works. In general much of the mechanical pumps are used for domestic and industrial purposes.

The recently completed National Irrigation Development Plan (NIDP) document by the Ministry of Agriculture has also mentioned the cost of development of shallow well to be about US$ 3000/ha (MOA, 1994). Hence there is a need to examine how the technology could be introduced at a cost which smallholders can afford.

Small earth dams

Runoff and rainwater are stored behind bunds and used for irrigation in Ifakara-Mangula in the Morogoro region. These bunds resemble the traditional water harvesting structures in India known as 'tanks'.

Rainfall is mainly concentrated during the wet season. Given the vast terrain and gentle slope, it is possible to construct small to medium earthen structures called tanks to collect and store the run-off during heavy rains for supplemental irrigation in the wet season and full irrigation in the dry season. These tank irrigation systems are very common in southern India, Sri Lanka and Northeast Thailand. The tanks also meet the village water needs in the dry season. Discussions with irrigation experts indicated that a few tanks are already available in the country, but the potential will be about 20 000 ha. whereas the technology is not explored on a large scale. The average cost of a tank to store about 30 000 m^3 of water is $ 4 000 which will irrigate about 2.5 ha of paddy or 5 ha of other crops.

Shallow wells (open/borewells)

Although shallow wells are not commonly used for irrigation, farmers are aware of the pumping technologies, as a few private farmers are using pumps for commercial crops like coffee and sugarcane. Hydrogeological studies have indicated that the water table is shallow in several locations. Therefore, it will be economical to invest in small pumps such as hand and manually operated treadle pumps. Regions such as Dodoma, Singida, Shinyanga, Tobora, Morogoro, Arusha, Coast region, Dar-es-Salaam and Mara, offer scope for groundwater exploitation through shallow wells.

Open wells can be constructed by providing wall or rings to a suitable depth in the case of alluvial strata or clay soils. Boreholes of 12 to 15 cm diameter can be drilled to a depth of 6-10 metres by providing suitable casing or strainer pipes. Hand or treadle pumps can be fitted in the wells. Pumps based on human power could only cover a small area. Hence pumps using either diesel or electrical power may also be installed wherever farmers show interest. A group of 3-4 farmers can jointly install a diesel engine operated pump, as electricity is not available in rural areas in several regions. Farmers are responsible for the operation and maintenance of their pumps. The 3 HP diesel pump costs US$ 300 to 400.

Malawi

Dambo irrigation

In dambo or dimba irrigation, farmers use mainly open hand-dug wells and watering cans. Recently, demonstrations of rope and washer hand pumps were introduced at 25 sites. The DOI is planning to initially introduce 200 treadle pumps with a possible expansion to 1 600.

According to DOI staff, current prices for rope and washer pumps are approximately US$ 25. The cost of a hand drilled well including the concrete slab and the pump installation is US$ 35. The cost for the first demonstration was shared between the DIS, which provided the equipment and material and the farmer who provided unskilled labour for the well drilling and the pump installation. During the expansion phase of this programme DOI expects farmers to bear the total cost of US$ 60.

There is much scope for the local manufacturing and use of these technologies, since out of a total area of 600 000 ha of dambos and flood plains, only about 119 000 ha are used. However, the area of dambos which can be developed for irrigation is the focus of an IFAD study.

Small earth dams

Another irrigation technology involves storing rainwater behind an earth bund and using it for supplementary irrigation in the rainy season and full irrigation in the dry season. Additionally

the dam can help recharge the groundwater which can be used for irrigation. The potential for this technology is very high due to the undulating terrain within the country. The DOI, through the IFAD programme, is surveying the existing earth dams and plans to use the data for the development of appropriate models.

Surface irrigation schemes

Government policy encourages the expansion of self-help small-scale smallholder irrigation schemes. The management of existing government operated schemes, mostly for rice production, will gradually be transferred to the beneficiaries. Improvement in the water diversion structures of the rice schemes, to reduce siltation, combined with canal lining and the introduction of other water control structures within the distribution network, is expected to substantially improve water management.

Sprinkler irrigation

There are three smallholder sprinkler schemes. The Kambwiri irrigation scheme was constructed two years ago, at a cost of about US$ 6 000/ha. This cost however included the technical assistance cost. The semi-portable sprinkler system with light galvanized handmoved laterals was adopted. The Diamphwe sprinkler scheme, was constructed in 1992 also at a cost of US$ 6 000/ha, including the technical assistance cost. In both cases the designed systems are based on imported light galvanized steel laterals and sprinklers. However the costs would have been reduced substantially by adopting the drag-hose system, which in addition to the lower cost, is less taxing to the women and repairs can be done by the farmers in the field. This system is successfully used in Zimbabwe. The cost of this sprinkler system is estimated at US$ 1 500 to US$ 2 000/ha. Existing PVC factories are already producing the PVC pipes needed for this system. The factories can also manufacture the reinforced hose.

In view of the above it may be concluded that design and specifications of sprinkler systems should aim at reducing costs. This can be achieved through the adoption of appropriate design procedures and systems which utilize locally produced components as much as possible. Additionally the import of sprinkler kits for local assembly would provide the added advantage of improved service on repairs in addition to cost reduction.

Zambia

Dambo irrigation

In the dambo irrigation at Choma, farmers are using open, hand-dug wells and watering the crops with cans and buckets. In another dambo irrigation at Kanchele in the Kaloma district, farmers installed a treadle pump to lift water from the 2.5 m diameter open dug wells.

Treadle pumps

The Kasisi Mission just outside Lusaka produces locally, a "treadle" pump which costs about US $ 153 and the cost is one of the reasons that the sale may be limited. There are individual treadles at Kafue, Nanga, Kalomo and other areas. FAO under its Food for Security programme is in the process of installing 20-30 of the Asian version of the treadle pump in Kafue, Kalomo, Chibombo and Mkushi.

Rope and washer

Kasisi made 15 rope and washer pumps for FAO. These pumps were distributed but the performance is not known.

First, the technology for various types of pumps exists within limited circles. Secondly, the prices are excessively high and unaffordable by almost all poor farmers individually. Thirdly, there seems to be little coordination or sharing of information by interested groups. No one is disseminating information nationally or regionally. Lastly, at the moment no one has a programme or even seems to understand that the marketing of the pumps is just as important as manufacturing them. All interested parties see pumps as part of a larger agricultural, health or irrigation scheme and hence have a very limited view. Pumps are only of interest in as much as they fit into overall and wider plans.

Small earthen dams/tanks

In the Nkandabwe irrigation scheme in Choma district, water is stored in a reservoir which is an abandoned coal mine. The water is released through a sluice and conveyed through a lined canal. Eighty-eight farmers each with an area of 0.2 ha share the water. Major crops grown are vegetables and maize.

Zimbabwe

Dambo irrigation

It is estimated that dambos comprise 1.3 million ha of land in the country, of which 0.26 million ha are in communal areas. It is also estimated that about 20 000 ha of these dambo lands are cultivated with food crops such as maize and vegetables being the major crops. Many dambos have dried up over years due to degradation of the upper catchments. The water table is comparatively deep and in locations such as the periphery of the dambos where the water table is shallow, community based irrigation is practised using manual pumps.

Manual pumps

Various types of manual pumps exist. The most common is the locally developed "bush pump" which is a deep-set pump. Treadle pumps are known, but they are not being marketed or manufactured on a continuous basis. Despite this there may be a place for deep-set pumps and probably a real possibility of drip irrigation. The bush pump costs US$ 1 000-1 500 according to local people in the field. The Asian deep-set could be considerably cheaper and provide the same capacity. To raise the groundwater table in the dambos and to prevent soil erosion, small earthen dams or tanks can be constructed across the streams to store the runoff water. This will help sustain smallholder irrigation.

Communal surface irrigation scheme

There are about 178 Government-developed communal and resettlement smallholder schemes. The Mushandike resettlement irrigation scheme has been operating since 1986-87. The scheme is managed both by Agritex and the community. Lined main canals are used to deliver water to the fields by surface methods. As the distance between the dam and irrigated area is 32 km, the cost of the canals is high. About 417 farmers irrigate about 620 ha. Each farmer owns 1.5 ha of land distributed in three blocks at the rate of 0.5 ha/person in each block. Major crops grown are maize, cotton, wheat and beans. Farmers pay operation and maintenance charges of $14.5/ha/year to the Government.

Sprinkler irrigation scheme

The Hema Mavhaire community sprinkler irrigation scheme in the Midlands has been in operation since 1992 and is managed by the community. Water is pumped from the nearby

dam using electric pumpsets. About 90 farmers own 90 ha at the rate of 1 ha/person. The drag hose sprinkler method is used to irrigate the crops. Groundnuts, maize and beans were grown during 1995-96. Farmers reported that they are paying about $ 14.5/ha/year as operation and maintenance charges to the Government. Even though, the electricity charges were not paid for earlier crop periods, they have since expressed their willingness to pay the charges.

Farmers reported that siltation is occurring in the dam due to catchment degradation, as soil erosion is the major problem. Farmers expressed fear that the storage may be reduced in due course. They are ready to invest in catchment management activities as such measures will ensure a sustainable water supply in the dam.

Irrigation by collector wells

The concept of collector wells has only been recently introduced in the country. Initially, the ODA made efforts to construct a few collector wells. For example, the collector wells in Muzondidya village and Chiredzi research station are about 2 m in diameter and about 18 m deep in both cases. Two horizontal boreholes at a length of 20 m are made at the bottom of the well. In one well, two hand pumps are fitted to lift the water which is used both for drinking and garden irrigation by the rural community. About 34 farmers irrigate approximately 0.3 ha using buckets. The other well is used to irrigate about 1 ha on the research station. The cost of the collector well will be about $ 8 000 - 9 000 per well including pumps. Since the wells are used also for rural drinking water supply, the water use for irrigation will be enhanced if low-cost drip or sprinkler methods are adopted.

Small earth dam/tanks

Another irrigation technology is to store rainwater behind an earthen dam/bund and use it for irrigation at appropriate locations. This dam can also help recharge the groundwater which can be used for irrigation. The potential for this technology is high due to the presence of undulating terrain in the country.

ECONOMICS OF IRRIGATION

The economics of crop production with different irrigation sources was worked out to compare the economic feasibility of irrigation investment with existing and improved technologies. Different irrigation technologies, input and output prices and break-even yields could be important to justify the future of irrigation technology transfer and uptake.

Tanzania

- The cost of irrigation per hectare varies from system to system. In the case of the traditional gravity system the annual (fixed) cost per hectare was US$ 16 compared to US$ 43/ha in the case of the improved gravity system (Table 1).
- Total cost of irrigation per hectare was US$ 26 for maize, US$ 27 for beans and US$ 38 for paddy under traditional gravity system and was US$ 53, US$ 55 and US$ 69 respectively under improved gravity systems (Table 1).
- In the case of the manually operated treadle pump the annual cost per hectare was US$ 49 compared with US$ 212 for diesel and US$ 152 for electric powered pumps (Table 2).

- Total cost of irrigation per hectare with 100 percent crop intensity was US$ 126 with the treadle pump, US$ 306 with a diesel pump and US$ 190 with an electric pump for maize. The costs were US$ 268, US$ 306 and US$ 229 for beans with the treadle, diesel and electric pumps respectively (Table 2).
- In the case of paddy, the costs were US$ 227, US$ 436 and US$ 305 respectively with the treadle, diesel and electric pumps. Since farmers normally go for two crops (i.e., at least 150% crop intensity), the profitability will be even higher.
- Irrigated yields are almost two times higher than the rainfed yields. The average yield of irrigated maize and paddy are about 2.5 t/ha and 3.5 t/ha respectively (Table 3).

TABLE 1
Cost of irrigation under gravity irrigation types (diversion schemes) in Tanzania

Costs	Traditional gravity	Improved gravity
Capital cost ($)	4145	16582
Average coverage (ha)	51	65
Life period (yrs)	10	15
Irrigation cost ($/ha):		
a. annual capital cost ($/ha)	16.28	43.67
b. maintenance cost ($/ha) (3% of capital cost)	0.50	1.30
c. labour cost ($/ha): wet season		
1. maize	9.10	8.18
2. baans	10.00	10.00
3. paddy	20.90	24.54
d. Total irrigation cost ($/ha)		
1. maize	25.88	53.15
2. beans	26.78	54.97
3. paddy	37.68	69.51

TABLE 2
Cost of irrigation under different pumping technologies in Tanzania

Items	Manual power	Mechanical powar	
	Treadla pump	Diesel	Electric
Capital cost ($)	100	1025	736
Averaga covaraga (ha)	0.4	2	2
Life period (Yrs)	5	10	10
Irrigation cost ($/ha):			
a. annual capital cost ($/ha):	49.11	212.17	152.35
b. maintenance cost (10% of capital cost)	5	21	15
c. labour cost ($/ha):			
1. maize	72.18	22.7	22.7
2. beans	88.18	22.82	22.82
3. paddy	173.18	246.45	244.54
d. energy cost ($/ha):			
1. maiza	-	50.18	39.27
2. beans	-	50.18	39.27
3. paddy	-	156.36	92.82
e. Total irrigation cost ($/ha/yaer):			
1. maize	126.29	306.07	190.07
2. beans	268.58	306.07	229.44
3. paddy	227.29	435.98	304.71

- Gross margin analyses indicate that beans are comparatively more profitable than maize and paddy. Irrigated crops yield almost four times higher gross margins than rainfed crops. However, paddy is remunerative in view of the higher crop value. Given the food security goals, irrigated maize is still a profitable option (Table 3).

TABLE 3
Economics of crop production in Tanzenie

Crop	Total cost (US $)	Yield (kg/ha)	Price (US$/ha)	Total revanue (US$/ha)	Break-even yield (kg/ha)	Gross margin (US$/ha)	Gross margin/ plot (US$)
Maize (rainfed)	109.2	1100	0.15	165	728	55.8	1395
Maize (irrigated)	177.8	2550	0.15	382.5	1185	204.7	51.2
Beans (rainfed)	140.5	400	0.64	256	220	115.5	28.9
Beans (irrigated)	214.3	980	0.64	627.2	335	412.9	103.2
Paddy (irrigated)	286.9	3550	0.15	532.5	1912	245.6	61.4

TABLE 4
Investment cost of different pumping technologies in Melawi

Items	Human power R & W pump	Mechanical power Treadle pump	With sprinkler Diesel	Electric
Capital cost ($)	60	100	1040	750
Average coverage (ha)	0.25	0.4	2.0	2.0
Life period (Yrs)	5	5	10	10
Irrigation cost ($/year):				
a. annual capital cost ($)	32	53	240	173
b. annual sprinkler cost ($)	-	-	904	904

Note: Cost of sprinkler system will be $ 1500 -2000. Life period will be 20 years. Replecement cost of sprinkler heeds will be $ 60/he after 10 yeers; Replecement cost of sprinkler hoses will be $ 72/ha every 5 years.

- Break-even crop yields indicate the safety margin in irrigated agriculture as average yields are almost 1.5 times higher than the hreak-even yields. Even with price or yield fluctuations farmers are ahle to manage that level of crop production.

Malawi

- In the case of rope and washer pumps, the annual cost per hectare was US$ 32 compared to US$ 53 in the case of the treadle pump. For mechanical equipment, the annual cost per hectare is US$ 240 and US$ 173 with diesel and electric pumps respectively (Table†4).

- Since the cost of irrigation was worked out with sprinkler systems, this cost is comparatively higher than the manual systems. Total cost of irrigation per hectare for maize with 100 percent cropping intensity was US$ 254 with rope and washer and US$ 231 with the treadle pump, US$ 1 576 with the diesel pump and US$ 1 393 with the electric pump. The costs were US$ 258, US$ 242, US$ 1651 and US$ 1 448 for beans respectively with the above systems. For cabbage, the costs were US$ 265, US$ 272, US$ 1 659 and US$ 1 454 respectively with the above irrigation sources. Since farmers normally go for two crops (i.e., at least 150 percent crop intensity), the profitability will be higher still (Table 5).

- Gross margin analyses indicate that vegetables are comparatively more profitable than maize. Average gross margin per hectare ranged from US$ 48 for rainfed maize to US$ 1 283 for irrigated maize. For beans, it was US$ 879, onion US$ 2 270 and for cabbage US$ 2 321.

TABLE 5
Cost of irrigation with varying technologies in Malawi

Items	Human power		Mechanical power	
	R & W pump	Treadle	Diesel	Electric
1. Fixad cost ($/ha)	128	132	240	173
With sprinklar	-	-	1144	1077
2. Variabla cost:				
i. maintanance cost	13	13	24	17
ii. labour cost ($/ha)				
1. maize	113	86	22	22
2. beans	117	97	25	25
3. onions	154	154	30	30
4. cabbage	124	127	27	27
iii. anargy cost ($/ha)				
1. maiza	-	-	146	104
2. beans	-	-	218	156
3. onion	-	-	350	250
4. cabbaga	-	-	224	160
c. Total irrigation cost	($/ha/year)			
(100 % crop intansity)				
1. maiza	254	231	1576	1393
2. baans	258	242	1651	1448
3. onion	295	299	1788	1547
4. cabbaga	265	272	1659	1454

Notas:

1. Fuel consumption will be about 0.3 lit/HP-hr and lubrication oil cost will ba about 10% of the fuel cost. Total hours of pumping per ha. wili be about 104 hrs for maize; 156 hrs for beans; 250 hrs for onion; 160 hrs for cabbaga. Diasel costs $ 0.56/litre.
2. R & W indicates rope and washer pump.

TABLE 6
Economics of crop production in Malawi

Crop	Total cost (US$)	Yield (kg/h)	Price (US$/kg)	Total revenue (US$/ha)	Break-even yield (kg/ha)	Gross margin (US$/ha)	Gross margin/plot (US$)
Maize (rainfed)	56.3	950	0.11	104.5	512	48.2	12.1
Maize (irrigated)	531.9	5500	0.33	1815	1612	1283.1	320.8
Beans (irrigatad)	520.7	2000	0.7	1400	744	879.3	219.8
Onion (irrigated)	1387.8	10450	0.35	3657.5	3965	2269.9	567.5
Cabbage	1178.9	17500	0.20	3500	5894	2321.1	580.3

- Break-even crop yields indicate the safety margin in irrigated agriculture. For vegetables, average yields are almost 2.5 times higher than the break-even yields. Even with price or yield fluctuations farmers can manage that level of crop production.

Zambia

- Cost of irrigation per hectare varies with the system used. In the case of traditional surface system the annual (fixed) cost per hectare was US$ 585 compared to US$ 218/ha with the rehabilitation system (Table 7).
- Total cost of irrigation (fixed and variable costs) was US$ 613 for maize, US$ 620 for tomato and is US$ 618 for onion with the traditional sur-face system and US$ 235 for maize, US$ 242 for tomato and US$ 240/ha for onion with the improved system (Table†7).

- For the manually operated treadle pump, the annual cost was US$ 85/ha and is US$ 258 for diesel and US$ 181 for electric powered pumps (Table 8).

- Total cost of irrigation was US$ 156/ha with the treadle pump, US$ 320/ha with the diesel pump and US$ 223 with the electric pump for maize at 100 percent crop intensity. The costs are US$ 182, US$ 323 and US$ 222/ha respectively for tomato with the treadle, diesel and electric pumps respectively at 100% crop intensity . Since farmers normally go for two crops (i.e., at least 150% crop intensity), the profitability will be higher still (Table 8).

TABLE 7
Cost of irrigation under surface systems in Zambia

Costs	Traditional gravity	Improved gravity
Capital cost ($)	2080	4850
Average coverage (ha)	160	10
Life period (yrs)	20	20
Irrigation cost ($/ha):		
a. annual capital cost ($/ha)	585	218
b. maintenance cost ($/ha) (3% of capital cost)	18	7
c. labour cost ($/ha):		
1. maize	10.80	10.80
2. tomato	17.44	17.44
3. onion	15.20	15.20
d. Total irrigation cost ($/ha)		
e. (100% crop intensity)		
maize	613.80	235.80
tomato	620.44	242.44
onion	618.20	240.20

Note: For new system completion, cost estimates for Mulumbi system were used where the main system will cost about $ 250/ha and tertiary development about $ 1 050/ha. For rehabilitation, data for Nkandabwe were used for computation where the main system rehabilitation will cost about $ 125/ha and tertiary system repairs will cost about $ 360/ha.

- Gross margin analyses indicate that vegetables are comparatively more profitable than maize and paddy. However, paddy is remunerative in view of the higher value of the crop. Given the food security goals, irrigated maize is still profitable (Table 9).

- Break-even crop yields indicate the safety margin in irrigated agriculture. Even with price or yield fluctuations farmers are able to manage that level of crop production (Table 9).

Zimbabwe

- Cost of irrigation per hectare was worked out for various pumping technologies, namely, sprinkler, drip and surface irrigation systems. Further, cost of irrigation with 'collector wells' was also analysed for financial viability.

- Data from the Hama Mavhaire irrigation system were used to analyse the cost of irrigation with sprinkler irrigation. Data from the Mushandike irrigation system were used to analyse the irrigation cost with the gravity system. Data from the collector well installed in Zaka were used to analyse the irrigation cost with that system. The cost of drip irrigation was computed taking into account yield differences observed between drip and other irrigation types at the Chiredzi research station. In general, for vegetables, a minimum of 20 percent higher yield was observed with drip compared to sprinkler irrigation. In all cases, data for 1995-96 were used.

- Productive life periods assumed int he analysis were: dam 40 years; scheme canals 20 years; pumping unit 15 years; sprinkler head and pipes 20 years; drag-hose 6 years; collector well 15 years (two hand pumps were used in the collector well and life was

TABLE 8
Cost of irrigation under different pumping technologies in Zambia

Items	Manual power	Mechanical power	
	Treadle pump	Diesel	Electric
Capital cost ($)	160	1125	786
Average coverage (ha)	0.4	2.0	2.0
Life period (yrs)	5	10	10
Irrigation cost ($/ha):			
a. annual capital cost ($/ha)	85	258	181
b. maintenance cost (10% of capital cost)	8.5	25.8	18.1
c. labour cost ($/ha):			
1. maize	62.18	19.80	19.80
2. tomato	88.18	17.44	17.44
3. onion	76.12	16.20	16.20
d. energy cost ($/ha):			
1. maize	-	16.34	4.22
2. tomato	-	32.18	5.70
3. onion	-	32.18	5.70
e. Total irrigation cost ($/ha/year): (100 % crop intensity)			
1. maize	155.68	319.94	223.12
2. tomato	333.40	222.24	181.68
3. onion	169.62	332.16	221.00

Note: Capital cost also includes the well drilling based on cheaper drilling technologies which accounts for roughly one-third of the capital cost. Maintenance cost will be about 10% of annual capital cost. Fuel consumption will be about 0.3 lit/HP-hr and lubrication oil cost will be about 10% of the fuel cost. Average cost of diesel will be about $ 0.25 per litre and electricity costs about $ 0.016/kwh. Even though the interest rate varies up to 60%, only 45% is used for computation.

TABLE 9
Economics of crop production in Zambia

Crop	Total cost (US$)	Yield (kg/ha)	Price (US$/kg)	Total revenue (US$/ha)	Break-even yield (kg/ha)	Gross margin (US$/ha)	Gross margin/ plot (US$)
Maize (rainfed)	124.7	1750	0.12	210	1039	85.3	21.3
Paddy (rainfed)	146.8	760	0.30	228	489	81.2	57.0
Cotton (rainfed)	121.6	700	0.22	154	553	32.4	8.1
Maize (irrigated)	172.5	5300	0.12	636	1438	463.5	115.9
Tomato (irrigated)	314.8	7500	0.13	975	2420	660.4	165.1
Onion (irrigated)	615.5	8550	0.21	1795.5	2931	1180	295
Cabbage	509.1	9800	0.16	1568	3181	1058.9	264.7
rape	250.8	4200	0.24	1008	1045	757.2	189.3
Paddy (irrigated)	328.4	4200	0.30	1260	1095	931.6	232.9

assumed to be 8 years. Interest rate was 12%. Efficiencies of the systems were as follows: sprinkler 75%; drip 85%; gravity 45% and manual irrigation from collector well 65%. Pump efficiency was 70%. Average cost of electricity was US$ 0.05/kwh or US$ 18/megalitre. Average cost of water from collector wells was about US$ 0.36/m^3.

- Total irrigation costs (annual and variable costs, excluding labour and energy costs) was US$ 1 518/ha for the sprinkler system; US$ 1 417/ha for the drip irrigation system; US$1 520/ha with the surface system and US$ 2 494/ha with the collector well system (Table 10).

TABLE 10
Cost of irrigation under different pumping technologies in Zimbabwe

Items	Sprinkler system	Drip system	Gravity system	Collector well
Capital cost ($)				
a. Dam	940295	940295	5330526	-
b. Well	-	-	-	7020
c. Scheme/equipment	202105	303158	1582500	912
Area covered (ha)	96	115	833	0.5
Irrigation cost ($/year):				
a. annual capital cost ($/ha/year)	1175	981	1010	-
1. Dam	-	-	-	2050
2. Wall	309	388	438	368
3. Schama/structure				
b. Maintenanca cost ($/ha/yaar)	34	48	72	76
c. Energy cost ($/ha)	62	62	-	-
d. Labour cost ($/ha)	7	7	40	129
e. Total irr. Cost ($/ha/year)	1654	1553	1600	2752
f. Gross margin ($/ha/year)	1840	2219	1821	2635

Assumptions: Life periods assumed are: dam 40 years; scheme canals 20 years; pumping unit 15 yaars; sprinkler head & pipas 20 yaars and drag-hosa 4 yaars; collactor wall 15 years; two hand pumps used in collector well and life will be 8 years. Interest rata 12%. Efficiency of sprinkler system 75%; drip system 85%; gravity system 45% and manual irrigation from collector well 65%. Pump efficiency 70%. Average cost of electricity $ 0.05/kwh or $ 18/megalitre. Average cost of water from collector well will ba about $ 0.35/m3.

- Total irrigation costs (including labour and energy costs) was US$ 1 654/ha with sprinkler irrigation; US$ 1 553/ha with drip system; US$1 600/ha under gravity system and US$2 752/ha with collector well. Even though farmers use sprinkler and drip systems with 250 to 300 percent crop intensity, a conservative estimate of 200 percent was used in the analysis for all the irrigation types (Table 10).

- Import and export parity prices were used in the gross margin calculations for maize and wheat crops. The export parity price for maize was US$ 0.15/kg and for wheat, the import parity price was US$ 0.27/kg. Total gross margin was US$ 1 840/ha with sprinkler; US$ 2 219/ha with drip system; $1 821/ha with surface system and $2 635/ha with collector well (Table 11).

  In the case of 'collector wells' even though the area irrigated was about 0.5 ha, the well also serves as a drinking water source for about 600 people in the rural area who consumed about 13 litres/person/day. Average cost was US$ 0.35/m^3. If two boreholes are drilled and two hand pumps installed, the cost would be about US$ 0.42/m^3, whereas a single borehole with motorized pump, would cost US$ 0.38/m^3. However, the success rate was less than 50 percent in the latter two cases. Hence, the viability of the scheme based on the gross margin from the community gardens could not be judged for the collector well.

- In the case of smallholder schemes, besides financial viability, other benefits such as employment generation, improved nutritional standards and improved market activities associated with forward and backward linkages are also common. These benefits can further justify the rationale for smallholder irrigation investment.

TABLE 11
Economics of crop production in Zimbabwe

Crop	Total cost (US$)	Yield (kg/ha)	Price (US$/kg)	Total revenue (US$/ha)	Break-even yield (kg/ha)	Gross margin (US$/ha)	Gross margin/plot (US$)
Maize (sprinkler)	264.3	7400	0.15	1110	1762	845.7	211.4
Ground nut (sprinkler)	258.1	2740	0.31	849.4	832	591.3	147.8
Sugar bean (sprinkler)	363.3	1940	0.7	1358	518	994.7	246.7
Cotton (surface)	432	2100	0.61	1281	635	849	212.3
Wheat (surface)	511.6	4000	0.27	1080	1894	568.4	250.1
Green maize (surface)	454.7	9600	0.15	1440	3031	985.3	246.3
Grain maize (surface)	363.2	8000	0.15	1200	2421	836.8	209.2
Tomato	618.2	14500	0.15	2175	4120	1556	389.2
Cabbage	593.2	23900	0.07	1673	8474	1079.8	270

- Break-even crop yields indicate the safety margin in irrigated agriculture. Even with price or yield fluctuations (risks) farmers can manage that level of crop production.

NATIONAL CAPACITY

Tanzania

Private manufacturing capacity

Import of modern equipment from Asian countries will be comparatively cheaper because of cheap labour and material costs. Though local suppliers are cautious about the quality of Asian products, it is argued that the Asian manufactured goods are able to adhere to the quality standards as seen by the increasing exports of pumps to other countries. The cost of the imported equipment from European countries is 3 to 4 times higher as compared to those from Asian countries.

It is further confirmed that several suppliers are eager to manufacture modern irrigation equipment locally through joint ventures. However, it is expected that incentives, in terms of credit facilities and concessions, to start the joint venture should be provided by the Government. Such joint ventures by local suppliers will help prices further and will also help improve local servicing and repair facilities. Such a venture will also increase employment opportunities of unemployed youth, as well as encourage the emergence of support services such as drilling equipment to complement the pump sector.

Local manufacture and application of modern irrigation technology particularly pumping equipment suffer from a number of drawbacks as it is highly dependent on materials and design transfers from industrialized countries. Often the technologies cannot be disseminated because of complicated designs or associated high costs. In several cases, the designs are too complex for local manufacturers to duplicate and use. Even if duplicated, repair and maintenance may be costly for the smallholders. Hence equipment, if imported should satisfy

two objectives: firstly, they should consider the goals of the smallholders, viz., supplemental or full irrigation, and secondly, they should take into account the financial resources of the smallholders, as the majority of them are poor.

Public sector capacity

The Institute for Promotion of Innovations (IPI) at the University of Dar-es-Salaam can be responsible for testing and fixing the required standards for pumps. CARMATEC at Arusha can be responsible for hand and treadle pumps and the Department of Agricultural Engineering and Land Planning at the Sokoine University of Agriculture, Morogoro can conduct the testing of agricultural machinery, including pumps.

Malawi

Private manufacturing capacity

Several potential manufacturers and irrigation companies in Lilongwe and Blantyre were contacted. Blueprints of the treadle pump, widely used in Asia, were made available by the consultants to a number of local manufacturers, to determine their capabilities of manufacturing this equipment locally. Cost estimates provided by potential manufacturers ranged from US$ 30 to US$ 50. It is the impression of the consultants that the quotations reflect the normal mark up of over 100 percent, common in this part of the world, due to the high interest rates currently prevailing (45 percent) and the high transportation cost of raw materials. The cost of locally manufactured PVC pipe and fittings is estimated to be US$ 15 for the standard 10 meter well depth. Considering well drilling and pump installation, total cost per unit would be from US$ 80 to US$ 100.

Small enterprises should also be investigated. It is very possible that cottage industry entrepreneurs can produce the pumps at lower prices because of smaller margins. However certain basic constraints exist in manufacturing this pump locally, i.e. newness of this technology to Malawi, high cost of materials, transport and credit for the manufacturing sector, small size of current market due to the farmers' lack of capital, relatively high cost of borehole drilling, lack of competition in irrigation equipment manufacture and current business practices operating at high mark-up of over 100 percent.

To ensure the local manufacturing sustainability the following are required: development of several manufacturers in different parts of the country to ensure competition and availability, development of quality control procedures and standards, increased private and public network to disseminate information and for sale of pumps, development of sales and advertisement materials and training of well drillers.

There are two local PVC pipe manufacturers, one in Lilongwe and the other in Blantyre. These manufacturers can also produce pipes for low-cost drip systems. However modifications are required to substitute the emitters with low-cost devices (spaghetti tubing, etc.).

Discussions with potential sprinkler manufacturers indicated that although foundries are available, the current demand for sprinklers in the country is too small to justify local manufacturing. However there is interest in importing sprinkler kits from Asia and assembling them locally. Such an approach is expected to further reduce the cost of these systems.

The irrigation pumps used in Malawi, are imported from South Africa, Europe and India. Electric motors are imported from Zimbabwe, Tanzania and South Africa. Diesel engines are imported from Europe and India. As an indication of costs, a 5 HP diesel driven pump sells for US$ 1 040 and an electric driven pump of the same size US$ 750.

Discussions with irrigation companies and potential manufacturers of pumps, indicate that in view of the small numbers of pumping units currently used, it is not advisable to undertake local manufacture of these items.

Public sector capacity

The DOI has a complement of 17 university graduates, nine of whom have post graduate degrees. Additionally there are 32 irrigation technicians (diploma level) and almost 100 technical assistants (certificate level). Most of this staff were outposted in the eight ADDs and can lead the promotion of irrigation technology and the demonstration of various technologies.

The Malawi Bureau of Standards (MBS), is the institution establishing national standards and monitoring the quality of products. It has laboratory facilities for developing the standards for manual pumps and providing the necessary quality control. It has also developed standards for PVC and polyethylene pipes and is monitoring the quality of these pipes.

The Malawi Industrial Research and Technology Development Centre (MIRTDC), is another institution which can assist local industry in manufacturing some of the irrigation equipment and technologies under consideration. The Polytechnic of the University of Malawi and the Department of Agricultural Engineering at Bunda Agricultural College can also be involved in studies related to the performance of the potential technologies under local conditions.

Zambia

Private sector manufacturing capacity

Many potential manufacturers and irrigation companies in Lusaka were contacted. Blueprints of the treadle pumps widely used in Asia were made available by the consultants to a number of local manufacturers to determine their capabilities of manufacturing them locally. One manufacturer has already made a sample treadle pump in plastic. The cost estimates provided by the manufacturers varied from US$ 40 (plastic version) to US$ 132 (sheet metal) per pump. High costs are due to expensive raw materials, higher interest rate as well as high profit margins.

There is no question that pumps can be manufactured in Zambia and at least the plastic/PVC version can be produced at a "reasonable" retail price. The total cost of pump and materials would be under US $ 60 for the 89 mm cylinder version. Since open dug wells are relatively cheap and done by local farmers, the total cost for pump, materials and well should be US$ 80-100. PVC pipe manufacturers in Lusaka could manufacture LDPE and LLDPE pipes from 8 to 100 mm diameter which can be used for low-cost drip system.

The irrigation pumps used in the country are imported mainly from South Africa, Zimbabwe, Europe, India and China. The costs are considered higher. As an indication of cost, a 7 HP diesel pump costs about US$ 2 000 and an electric 2 HP pump costs about US$

700. The local suppliers have shown keen interest to import equipment from Asian countries and when the demand has improved, they will manufacture locally as a joint venture.

Public sector capacity

The irrigation section at the Ministry of Agriculture, Food and Fisheries (MAFF), is headed by a chief agricultural specialist who is supported by three principal agricultural specialists at the headquarters. There are about seven technical persons working in each province. Apart from these persons, 29 teams each with one specialist and seven technical persons are placed in different districts. In total, there are about 350 persons working in the section.

The School of Engineering at the University of Zambia has a Department of Agricultural Engineering which offers degree programmes in Agricultural Engineering. The School of Agriculture offers degree programmes in agriculture. The Natural Resources Development College is offering diploma courses in water engineering and also imparts in-service training to the staff of the various departments.

The Chapula Zambia Centre for Horticultural Training at Kalulushi has been conducting irrigation courses for the past several years. The courses cover irrigation methods, water distribution, pumps and pumping station and measurement of water. Small-scale farmers have also received training there. The Technology Development and Advisory Unit, University of Zambia provides technical assistance in testing and re-designing of equipment to suit the Zambian conditions. They have also been involved in testing various hand pumps.

Zimbabwe

Private sector manufacturing capacity

Manual pumps

Various types of manual pumps exist. The most common is the locally developed "bush pump" which is a deep-set pump. Treadle pumps are known but no one has ever demonstrated and marketed them on a large scale, nor is anyone marketing or manufacturing them on a continuous basis.

Several NGOs are involved with the use of treadle pumps. The Intermediate Technology Development Group (ITDG) has shown them to its clients. CARE is utilizing them in their projects. They use the ATI version which sells for about US$ 175. Since water tables are low (deeper than 6 metres) in most areas and because of the lack of dambo exploitation and the 30 metre prohibition zone near rivers or waterways, the use of the treadle and other low-cost pumps may be much more limited in Zimbabwe. However, there are areas where water tables are appropriate or where irrigation near rivers is possible.

Nevertheless, there may be a place for deep-set pumps and probably a real possibility for drip irrigation. The bush pump costs US$ 1 000-1 500 according to local people in the field. This appears to be the installed rather than the pumphead price which is now selling for US$ 500. The Asian deep-set pump could be considerably cheaper and provide the same capacity

Other pumps and equipment

While most irrigation equipment from pumps to sprinklers to drip irrigation is imported, the local capacity to produce low-cost appropriate technology exists in abundance. There are many companies dealing with irrigation equipment. All are run by Zimbabweans and were

established many years ago. These companies are dealing with mainly sprinkler and micro irrigation equipment. The company takes the responsibility for designing, installing and manufacturing the equipment.

Suppliers of irrigation equipment and services are usually companies which design, supply, install and service the equipment. These companies have direct contact with the farmers. Some of these companies also manufacture some of the equipment they supply while others get the equipment from local manufacturers or import. Many suppliers purchase aluminium and PVC pipes from local manufacturers and then fabricate them into end products at their factories. The sprinkler nozzles are also locally fabricated. Most of the components except drippers and lateral lines with inlet drippers are locally made.

Public sector capacity

The Department of AGRITEX has three divisions: Irrigation, Soil and Water Conservation and Agricultural Engineering. At headquarters, the technical and field staff are very competent. There are also field staff based at the provincial and district levels providing extension services in all aspects of irrigation and agriculture.

The Agricultural Development Agency (ADA) helps farmers implement irrigation schemes. The commercial farmers' union and various other commodity associations also help farmers in various activities. There are also other national organizations and institutions which contribute to irrigation technology.

The University of Zimbabwe has a Department of Agricultural Engineering offering degrees in Agricultural Engineering and has a proposal to start training in irrigation at a master's degree level. They also conduct research particularly in the area of drip irrigation with wheat for commercial farmers and low-cost drip systems for smallholders. The Department has 17 qualified persons in various disciplines.

The ZITC at Harare tests irrigation equipment such as pumps, pipes, sprinklers and drippers, providing the means for local companies to provide quality equipment. ZITC also participates in establishing standards for irrigation equipment with the Zimbabwe Standards Association (ZSA).

The Chidrezi Research Station with its two substations conducts irrigation and agricultural research for Area 5 which has the lowest rainfall. Research activities at this station covers agronomy, low-cost irrigation techniques, irrigation of rainfed crops, horticulture and vegetables. The research on subsurface micro irrigation using clay pipes and shallow wells is impressive and will be helpful to the smallholder where water is scarce.

In view of the above, it may be concluded that the national capacity is capable of meeting the challenge of introducing new irrigation technologies with limited technical assistance under the south to south cooperation programme.

Transferring Experiences in Irrigation Equipment Manufacture

At present most of the irrigation equipment such as electric motors and pumpsets, diesel engines, submersible pumps, sprinkler and drip irrigation systems used in these four countries

are imported mainly from European countries such as England, The Netherlands, Italy, Germany and Finland, and some from South Africa and Israel. The cost of this equipment is very high, hence smallholders cannot afford to invest in pumping and irrigation equipment. Further, it is difficult to get local servicing as spare parts are not readily available from suppliers. The equipment can be obtained at comparatively lower prices from the Asian countries where the prices are only one-half to one-third of the currently imported prices (Table 12). There is a need also to manufacture the equipment locally to reduce the costs and provide prompt service and maintenance.

TABLE 12
Cost of locally manufactured and imported irrigation equipment from Europe end South east Asie

Equipment	Locel TANIRA	Imported INTERTEC	Europe MERRY	STORK	SWN	SE ASIA
Hand pump:						
5 m depth	465	670	1000	2500	400-700	40-55
20 m depth	860	-	-	-	-	-
Treadle pump:	-	-	-	-	-	40-65
River pump:						35-40
Diesel pump:						
2 HP	-	-	2000	-	-	-
3 HP	-	-	-	-	-	630
5 HP	-	-	-	-	-	658
Electric pump:						
Monobloc:						
1 HP	-	-	-	-	-	105
2 HP	-	-	-	-	-	150
3 HP	-	-	-	-	-	285
5 HP	-	-	-	-	-	350
Centrifugel pump:						
1 HP	-	700	-	-	-	150
2 HP	-	-	600	-	-	190
3 HP	-	-	-	-	-	240
5 HP	-	-	-	3000	-	320
Submersible pump:						
1 HP	-	-	-	2000	-	-
2 HP	-	-	9000	-	-	350
3 HP	-	-	-	-	-	400
5 HP	-	-	-	4500	-	455

Note: Only hand pumps are manufactured in Tanzania. Hand/Manuel pumps from South East (SE) Asia refer avarage cost in Viat Nam/Nepal/Bangladesh/India and mechanical powered pumps in India, if importad. The cost reported includes transportation cost 15-20%, import duty/tax 5%; ship clearance charge 2-5%.

Experiences of the developing countries in Asia can be transferred so that local manufacturers can produce the equipment at a lower price. Many suppliers have reported that they will first import the equipment from the Asian countries and after evaluating the performance and the demand for the equipment, they will manufacture them locally. Several manufacturers in Asia such as those in India, are already exporting the equipment to several countries including a few in Africa.

Three or four interested manufacturers in each of the four African countries can be selected and sent to Asian countries such as India, China and Malaysia to explore the possibilities for importing the technologies to African countries. This includes the importation of parts as well as assembling in the African countries before starting to manufacture fully. During the visit, the African suppliers could also get the opportunity to discuss with various Government organizations and farmers, the performance of these equipment for large scale

adoption. The visit should include 16 suppliers, four in each country for two weeks. The selection of promising suppliers can be done based on their current sale of imported equipment, organizational structure, asset base and scope for future expansion.

Further, it is recommended that competent technicians from India be sent to the irrigation pumping and equipment sectors to provide on-the-job training on the production and maintenance of the equipment. This is especially true for Zimbabwe, where various types of pumps and other equipment are manufactured. At first, four technicians specializing in different technologies can visit for four weeks each.

TRANSFER OF LOW-COST IRRIGATION TECHNOLOGY

Asia accounts for more than two-thirds of the irrigated area in the world and India's share represents one-third. Investments in new projects and rehabilitation of the traditional gravity systems have contributed to area and production increases. The irrigation development started with small gravity systems, followed by large scale reservoirs. Pumping technology coupled with rural electrification made a significant contribution to food production and regional development.

Further, research on irrigation water management including conveyance and application methods incorporating the soil and climatic factors by the research institutions complemented the production increases. Introduction of state-of-the-art irrigation equipment technology by manufacturers is a significant breakthrough in the expansion of pumping technologies.

The successful experiences from southern India in irrigation and pumping technologies will attract the African smallholders. The Indian rainfall pattern, soil type, cropping pattern and terrain are more or less comparable to African conditions. However, comparatively higher per caput water availability in these African countries, lower level of food production per unit of land and water, and inefficient water use and management warrant the need for technology transfer from developed regions, like India, to African countries.

In India, currently, about 26 agricultural universities with several hundred research stations are involved in the irrigation technology transfer to farmers. More specifically, the level of irrigation research conducted by private manufacturers with their strong research and development departments, at farm level, for different crops, types of pumps and other drip and sprinkler equipment, should be examined. In addition, the extent of irrigation technology transferred from research stations and from manufacturers to farmers in India should also be examined in depth. These reviews are necessary considering the irrigation development and food security for African nations.

ASSESSMENT OF SUITABILITY OF THE IRRIGATION EQUIPMENT IN AFRICA

The Indian subcontinent matches well with African conditions particularly in terms of rainfall, soil type, cropping pattern and irrigation. Pumping technology is well established there and various pump types are used depending upon the water table. The Indian equipment is well suited to the African conditions as a few Indian companies have already supplied pumps to some African countries. Since the cost of Indian pumps is comparatively lower, it will be easily accepted by both suppliers and farmers, as most of the smallholders in those African

countries own around 2 ha or less. In India the small and marginal farmers who account for about 70 percent of the farming community own about 1 ha and use mostly electric powered pumps. In locations where electricity supply is inadequate, diesel powered pumps are used. Manual pumps such as treadle pumps are used in states like Bihar, Orissa and parts of West Bengal where the water table is shallow.

In the four African countries visited, irrigation water for crop production is obtained from rivers and streams both by gravity and pumping methods. In several locations pumping groundwater is also common using either manual or mechanical pumps. Normally, when the water table is 6-7 metres high, manually operated pumps such as hand, rope and washer and treadle pumps are used. Hand and treadle pumps are also used in India and will be suitable for African conditions. Indian Mark II pumps are already in use in several African countries mostly for rural water supply projects under the UNICEF programme. A few suppliers had also imported these pumps.

Mechanical pumps such as submersible and diesel engine pumps from India were imported by a few suppliers in Malawi and Zambia and it is reported that the demand may be increasing.

The major component of well investment is the construction. In India, there is a large variety of drilling equipment. These range from slurry sludge and hand boring sets for shallow wells, to rotary drills for making deep bores in alluvium soils and percussion and hammer drills for making deep bores in hardrock areas. Furthermore, advanced mechanical drills are also available to make horizontal and vertical boreholes inside the wells to a length of 30-40 metres. In Zimbabwe, collector wells with horizontal boreholes are drilled to a length of about 30 metres at the bottom of the open wells which are 15-20 metres deep. Currently, well drilling is a very costly operation in all of the African countries. The drilling equipment and technologies available in India can easily satisfy the needs of the African smallholders for all types of well construction at a comparatively lower rate.

Sprinkler and drip irrigation equipment is also manufactured and widely used in several states in India. The Premier Irrigation Equipment Company is particularly well known for sprinkler equipment and the Jain Drip Irrigation Company is well-known for drip irrigation. These companies are already exporting irrigation equipment components to USA, several European and a few African countries. Smallholders in the African countries have already been exposed to drip and sprinkler irrigation systems due to the extensive use of these systems in the large private and government estates. However, this technology cannot be adopted by all smallholders due to its high cost. The cost will be comparatively lower when the equipment is imported from India.

COST PRICE CONSIDERATION

Invariably in all the countries the price of the irrigation equipment is higher than if it were imported from India For example, the hand pump (up to 5 m depth), costs US$ 60 to US$ 120 compared to US$ 500 to US$ 600 in Tanzania. The cost of an imported 5 HP electric pump from India costs US$ 300 to US$ 350 compared to the prevailing price of US$ 700 for one imported from European countries. A 5 HP diesel set, from India costs US$ 600 to US$ 700 compared to US$ 1 000 to US$ 2 000 in Tanzania, Malawi and Zambia. In Zimbabwe, a 15HP engine imported from Europe costs about US$ 6 000. Aluminium pipes cost about US$

20 per 5.5 m length if imported from India while those locally made cost about US$ 37 in Zimbabwe. The cost of a standard sprinkler nozzle if imported will be about US$ 5 whereas it costs about US$ 10 in all the four countries. Detailed comparisons of the imported prices from Europe and Asian countries are given in Table 12.

In Tanzania, Malawi and Zambia all the equipment are imported either from Europe or South Africa. However, small components like PVC pipes are locally made. In Zimbabwe alone, most of the equipment is manufactured and some are imported from Europe South Africa and USA.

One of the components of the high cost of importation is the duty for the equipment and raw materials used for manufacturing the equipment. For example, in Tanzania, the import duty is only 5%. In Malawi, even though there is no duty for the agricultural equipment, a 20% surtax is levied on the accessories of agricultural equipment. In Zambia although a tax concession was announced by the Government in the current budget, the suppliers reported that it had not been implemented. Currently, imported equipment attracts a 15% duty and 20% VAT In Zimbabwe, despite no duty for the equipment, a 10-15% tax is levied on imports related to agriculture. In general, the local suppliers and manufacturers argued that imported equipment may be cheaper than those locally manufactured because of the import duty for the raw materials, high labour costs and low demand for the product. However, costs may be reduced if imported from India or manufactured locally in joint ventures with Indian companies. Once costs are reduced and local servicing facilities are available, then increases in demand for the equipment may be possible

Conclusion and Recommendations

The overall government policy in these African countries is to promote social and economic development through irrigated agriculture which is sustainable over time, economically justified, financially viable, socially acceptable and technically sound, without causing unacceptable impacts on the environment. Irrigation development programmes must also benefit as many households as possible and in particular those that belong to the most vulnerable groups of the rural community. Irrigation development, particularly small-scale irrigation, will be an important component of a diversification and expansion strategy to strengthen food security for the future. There is a need to identify crops and irrigation techniques which will give higher returns to irrigation water and overall investment. The best and most economical uses of water for irrigation are essential to any strategy of irrigation development. The following are the conclusions and the recommendations which may be relevant to the four countries covered.

Tanzania

Diversion schemes demand more area but the efficiency is less Hence, there is an urgent need to rehabilitate the schemes by restructuring weirs and lining the canals with prefabricated slabs. Treadle pumps can be introduced where the water table is within 6-7 m in several locations and particularly where the diversion schemes are not benefiting the smallholders Low-pressure and low-cost sprinklers perform well in the hill areas. Therefore, these systems can be introduced in the hill diversion schemes. The country's undulating terrain is very suitable for small earth dams (tanks) to provide supplemental irrigation in the wet season and direct irrigation in the dry season. Since the duration of the water supply in many schemes is

not adequate to cover the entire season, shallow tube wells or open wells can be constructed to raise nurseries before the rains and to irrigate the crops when the canals dry.

Malawi

The extent of dambos with potential for irrigation development warrants the introduction of a number of manual irrigation pumps and their local manufacture. The combination of low-cost drip systems with manual pumps, should be tried and demonstrated. The current practice of hand dug shallow open wells should be encouraged. Alternative low-cost drilling techniques such as slurry sludge, and hand auger drilling should be promoted. The country's undulating terrain is very suitable for small earth dams both for direct irrigation and the recharge of the groundwater to be used for irrigation. As such this technology should be promoted. The transfer of government schemes to community management after improvement should incorporate the feasibility of introducing the lining of the field canals. The encouraging results from the first few sprinkler systems introduced in community operated and managed irrigation schemes should be continuously monitored. Minor changes in the design of future sprinkler schemes should be introduced to reduce costs and provide individual plots for every family. While it is appreciated that the current small market for sprinklers does not justify the manufacturing of this equipment, local assembly of sprinklers is recommended, as it would reduce their cost and improve the availability of spares and service for their maintenance. Technical assistance for on-the-job training of the DOI staff in planning, designing and supervision of small-scale irrigation schemes is also recommended.

Zambia

The extent of dambos with potential for irrigation development warrants the introduction of locally manufactured manual irrigation pumps. Low cost well drilling technologies should be introduced and a combination of low-cost drip system with manual pumps and pitcher irrigation should be tried and demonstrated. The undulating terrain of the country is suitable for small earthen dams both for direct irrigation and for recharging the groundwater for irrigation. This technology should be promoted and implemented.

Transfer of government schemes to the community after improvement should incorporate the feasibility of introducing the lining of the field canals, water control and regulating structures.

Technical assistance for on-the-job training of the staff of the irrigation section in planning, designing and supervision of the small-scale structures is also recommended. Certain regions have access to electricity, thus electric powered pumps can be introduced, as groundwater is easily available. The pumps could be imported at a comparatively low cost from Asian countries.

Zimbabwe

As a result of the encouraging results from the few smallholder drag-hose sprinkler irrigation systems in the community operated and managed projects, the introduction of many such schemes in the future mainly to save water and increase crop production, is recommended. On individual smallholder farms, introduction of low-cost drip irrigation and low-cost low-pressure sprinkler irrigation systems will improve water use efficiency and crop productivity.

Since shallow alluvial aquifers are found only in selected provinces, manual pumps can be introduced to exploit them.

Since collector wells were recently introduced and serve both rural water supply and community garden water requirements, the expansion of such a high-cost investment for irrigation should be carefully analysed. Small check dams or percolation ponds should be constructed in the catchment areas mainly to reduce soil erosion and siltation in the downstream dams. Small earth dams or irrigation tanks should be constructed to store the rainfall run-off for irrigation and for recharging the groundwater. The inadequate rainfall and undulating terrain in the country will facilitate such structures.

The cost of the locally manufactured and imported pumps and equipment in the country is comparatively high. It is recommended that the equipment be imported from Asian countries initially and subsequently to encourage joint ventures to manufacture them. Technical assistance for on-the-job training for the staff of the AGRITEX in planning, design, implementation and supervision of the small-scale systems should be provided.

Regarding the economics of irrigation, break-even crop yields indicate the safety margin in irrigated agriculture. Even with price or yield fluctuations (risks) farmers are able to manage the crop production. Viability of different irrigation schemes based on the gross margin justifies the need for irrigation technology transfer in all these countries. In the case of smallholder schemes, besides financial viability, other benefits such as employment generation, improved nutritional standards of people and improved market activities associated with forward and backward linkages are also common. These factors further justify the rationale for smallholder irrigation investment.

A country action programme aimed at various irrigation technologies and the establishment of a national irrigation technology demonstration center is recommended for all the countries.

References

FAO. 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Country Mission Report - Tanzania by R.K. Sivanappan, K. Palanisami, L.A. Egan and R.L. Daluti, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

FAO. 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Country Mission Report - Malawi by R.K. Sivanappan, K. Palanisami, L.A. Egan and C.P. Mzembe and A.P. Savva, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

FAO. 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Country Mission Report - Zambia by R.K. Sivanappan, K. Palanisami, L.A. Egan and A.E. Daka, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

FAO. 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Country Mission Report - Zimbabwe by R.K. Sivanappan, K. Palanisami,

L.A. Egan and R.J. Chitsiko, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

FAO. 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Irrigation Economists - Tanzania, Malawi, Zambia, Zimbabwe, by K. Palanisami, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

FAO. 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Project Proposal to Transfer of Irrigation Equipment Manufacture and Low-Cost Irrigation Technology - Experiences from Asia, Mission Report by R.K. Sivanappan and K. Palanisami, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

FAO 1966. Water Development for Food Security, Irrigation Technology Transfer to East and Southern Africa, Report on the Irrigation Equipment Manufacture Sector in India, Mission Report, by R. K. Sivanappan and K. Palanisami, Water Resources Development and Management Service, Land and Water Development Division, Rome, July 1996.

Funding irrigation development in Kenya with special reference to funding by the Smallholder Irrigation Scheme Development Organization

FORMATION OF THE SMALLHOLDER IRRIGATION SCHEME DEVELOPMENT ORGANIZATION

The economy of Kenya relies on Agriculture. Eighty percent of the country is arid or semi-arid. In the arid and semi-arid areas sustainable agriculture can only be achieved through well planned and operated irrigation. The Government of Kenya has identified irrigation as an important tool for improving food self-sufficiency and enhancing household incomes in the rural sector.

In the past, irrigation development has had the following characteristics:

- Projects were identified by donors or donors determined the project location.
- Projects were designed by expatriates attached to the donor community who also supervised the implementation, operation and maintenance works
- Projects were funded almost virtually by donor funds
- Projects were identified more or less on an ad hoc basis and there was very little or no participation by the beneficiaries in project preparation and development.

The result of the above approaches was that projects were implemented on the basis of their potential for development rather than on demand for the facility. Many of the projects are no longer in operation and farmers are awaiting outside support to revive these projects. Some projects are operating very inefficiently while others are still operating but rely on outside support.

In 1989, the Ministry of Agriculture (MoA) conducted a review of irrigation development. It was evident that donor funds were becoming increasingly limited. It was also noted that those projects implemented earlier, without full farmer participation were not sustainable and were a continuous drain on the government funds. The MoA created the Smallholder Irrigation Scheme Development Organization (SISDO) to manage a revolving fund for irrigation development. This organization also ensured farmers' participation in planning, implementation and operation of irrigation projects.

SISDO was formed in 1991 with the assistance of the MoA and the approval of the Ministry of Finance and Economic Development. The organization signed a memorandum of understanding with the MoA setting out how it would operate in development of irrigation activities. Currently the organization is an independent body with its own management and Board of Directors.

M.K. Gakundi
General Manager, Smallholder Irrigation Scheme Development Organization, Kenya

Objectives of SISDO

The organization's main objective is to improve the standard of living of smallholder farmers/groups by assisting them to develop and manage sustainable income generating projects without having to seek outside assistance.

The organization aims to create a revolving fund from which farmers can borrow for scheme development without having to always rely on donor funds.

Start up of SISDO operations

SISDO began major operations in 1992. It started with projects earlier identified by the Ministry of Agriculture. Some of these projects were ongoing and needed either rehabilitation or upgrading. Currently the organization is working on projects identified by the beneficiaries but it still relies on irrigation and drainage project profiles drawn by the Irrigation and Drainage Branch (IDB) of the Ministry of Agriculture.

During the few years of operation, the SISDO has realized that maximum results are achieved when there is cooperation with all organizations involved in similar activities - government, non-governmental institutions and the communities.

SISDO Loan programmes

SISDO is currently involved in the following programmes:

i. Development of group-based irrigation projects developed with and managed by the farmers.

ii. Development of pump-fed irrigation systems for individual farmers in clusters.

iii. Provision of farm inputs to groups of farmers in irrigation schemes (normally women who make up the majority of agriculture farm workers).

iv. Provision of high grade milk cows farmers' groups. This is the high stage for farmers who have excelled in utilization of farm input loans.

SISDO plans to become involved in :

i. Provision of credit to small-scale traders in rural and urban centres for various enterprises.

ii. Lending to individuals for irrigation development. Involvement in this area has become necessary as a result of the numerous requests received from individual farmers for irrigation development.

In 1995 the Cooperative Bank of Kenya agreed to handle lending issues while SISDO concentrates on identification and preparation of groups who could be assisted and in follow-up during loan repayment period. Other commercial banks have expressed interest to work with SISDO. Under this scheme:

- SISDO will deposit a guarantee fund to the bank equal to 70% of the project cost. This ratio will be reduced as smallholder credit worthiness is proved through good loan repayments.
- The farmer will contribute 15% of the project cost and deposit it with the Bank. Thus the loan required is 85% cash secured.

SISDO is working to sensitize commercial banks to also start providing credit to smallholders, hence the cooperation.

SISDO'S ACHIEVEMENTS

Achievements in Infrastructure Loan Programme

SISDO has prepared and assisted farmers to install irrigation infrastructure in five schemes which are already operational. These include:

- Mukurira Kiambongo in Meru
- Mwethya Muveleki in Makueni
- Kagati in Nyeri
- Mbanya in Machakos
- Ciambaraga project in Tharaka Nithi

Repayment has started in Mukurira Kiambongo, Mwethya Muveleki and Kagati.

Many other projects are in various stages: preparation, surveys, designs, farmers training/mobilization and repayment of security fund. The following four are in the final stages prior to implementation.

- Mwicuiri project in Karatina region is in the final stage of raising the security fund. Surveys, designs and tendering have been finalized and a contractor identified. Construction is due to commence in April, 1997.
- Ruungu project in Meru region is being implemented.
- Tumaini and Matangini projects in Machakos region are under preparation. They have contributed the necessary security fund of Kshs 500/- per farmer for famine relief areas. Implementation is planned to begin in 1997.

SISDO has prepared and financed one group of 17 farmers in Mitunguu Irrigation to replace their outdated and malfunctioning irrigation equipment (pipes and sprinklers). A second group is being prepared. Tables 1 and 2 show the organization's achievements and the progress of the irrigation infrastructure loan programme.

Achievements in Farm Inputs Programme

Fifty-four groups from Makueni, Meru, Kirinyaga and Nyeri have received credit for farm inputs. Some of the groups are on their second and third loans. Groups range from 20-35 members with loans varying from Kshs 3 000 to Kshs 15 000 per farmer depending on the area to be cultivated. Loan repayments have been good with most groups achieving 100 percent repayments on time. The achievements and progress of the farm inputs programme are shown in Table 3.

TABLE 1
Achievements in irrigation infrastructure loan programme

Project	District	Value (Kshs)	Status
Mwethya Muveleki	Makueni	728,730.00 63 farmers 30 acres	Project implemented Loan repayment in progress - 74 percent repayment
Mukuria Kiambongo	Meru	704,949.50 15 farmars 15 acres	Project implemented Farmars repaying loan since Nov. '95 Repayment rate 100 percent
Kagati	Nyari	2.2 Million 41 farmers 41 acres	Project implemented Farmars repaying loan since Aug. 96. Repayment 100%
Ciambaraga	Tharaka Nithi	10.2 Million 135 farmers 135 acres	Designs and Tendering have been finalized. Construction work in final stages.
Mbanya	Makueni	1.2 Million 63 farmars 30 acres	Construction works finished in Novamber, 1996. Loan repaymant to start in January 1997.
Ruungu	Tharaka Nithi	4 Million 160 farmers 160 acres	Preparation of design and tender documents finalized Tendering done in Aug. '96. Construction in progress.
Mwicuri	Nyeri	15 Million 250 farmars 125 acras	Designs and tender documents ready Farmars finalizing payment of security fund.
Total		33.2 Million 727 Farmars 536 Acres	

TABLE 2
Progress in Irrigation Infrastructure loan programme

No	Project	Mobilization	Investigations design tendering	Implementation	Operationel Loan repayment	Project Cost
1	Mukuria Kiambogo					740,000
2	Mwethya Muveleki					820 000
3	Kegati					2 200.00
4	Ciambaraga					10,000,000
5	Rungu					4,000,000
6	Mwicuiri					14,000,000
7	Mbanya					1.500,000
8	Tumaini					1,500,000
9	Kionyo					7,000,000
10	Matangini					1,570,000
11	Nthambo					Under Preparation
12	Lower Kithangeri					Under Preparation
13	Kunati					Under Preparation
14	Kamoko					Under Preparation
15	Muteithia					Under Preparation
16	Mahianyu					Under Preparation
17	Chebutwa					Under Preparation
18	Majengo					Under Preparation
19	Marodo					Under Preparation
20	Mukuri Mbugi					Under Preparation
21	Gichucha					Under Preparation
22	Njukini					Under Preparation
23	Miwaleni					7,000,000
24	Kiambaa					Under Preparation

TABLE 3

Implemented/funded projects (as of February, 1997) farm inputs

Project	District	Date disbursed	Amount disbursed	Amount payable	Amount repaid	Balance
Segena	Nyeri	June 93	626 974	739 829	204 754	524 785
Mwireri	Nyeri	June 93	184 568	217 790	230 073	0
Wendeni	Nyeri	June 93	125 321	212 843	214 287	0
Warumwe	Nyeri	June 93	218 961	258 374	264 121	0
Karikoni	Kirinyaga	June 93	90 000	90 000	60 317	29 683
Nyakio	Kirinyaga	June 93	75 000	75 000	41 881	33 119
Mugumo 1	Kirinyaga	June 93	151 175	178 000	178 800	0
Gitaga 1	Kirinyaga	June 93	181 410	214 062	214 560	0
Ragati 1	Kirinyaga	June 93	154 645	182 481	183 375	0
Arimi 1	Maru	June 93	389 467	411 970	152 039	259 931
Mugumo 2	Kiriyaga	June 93	47 988	55 800	55 800	0
Gitaga 2	Kirinyaga	June 93	49 538	57 600	57 800	0
Ragati 2	Kirinyaga	June 93	17 716	20 905	20 600	305
Ivueo	Makueni	Apri 94	90 550	106 849	91 112	15 737
Kiumoni	Makueni	Apri 94	90 550	106 849	94 812	12 037
Wikwatyo	Makueni	Apri 94	90 550	106 849	90 512	16 337
Keliani	Makueni	Apri 94	90 550	106 949	96 512	10 437
Mugumo 3	Kirinyaga	Apri 94	98 647	116 403	50 706	65 697
Gitaga	Kirinyaga	Apri 94	77 062	90 933	56 700	34 233
Ragati 3	Kirinyaga	Apri 94	63 167	74 537	32 199	42 338
Waraza 1	Nyeri	Oct 94	280 810	331 356	322 775	8 581
Kimahuri	Nyeri	Oct 94	351 090	414 286	345 000	69 286
Mwicuina	Maru	Oct 94	125 946	136 444	108 960	27 484
Mwangaza 1	Nyeri	Mar 95	234 780	277 040	273 000	4 040
Wendani	Nyeri	Mar 95	53 054	62 604	39 995	22 609
Mwirari	Nyeri	Mar 95	8 643	10 199	10 050	149
Warumwe	Nyeri	Mar 95	34 983	41 280	21 373	19 907
Mwicuine	Maru	Mar 95	44 132	44 132	0	44 132
Arimi 2	Meru	Mar 95	205 470	227 707	168 490	59 217
Rongai	Nyeri	July 95	214 631	253 265	94 500	158 765
Mwangaza 2	Nyeri	July 95	195 900	231 162	105 000	126 162
Kebati 1	Nyeri	July 95	183 938	217 044	189 841	27 203
Mwihoko	Nyeri	July 95	211 443	249 503	0	249 504
Mugumo 4	Kirinyaga	July 95	19 000	228 920	228 920	0
Gitaga 4	Kirinyaga	July 95	2 411 756	285 272	285 272	0
Ragati 4	Kirinyaga	July 95	114 339	134 920	67 122	67 798
Waraza 2	Nyari	Oct 95	211 850	276 120	92 000	184 120
Mima	Nyari	Oct 95	157 380	183 000	110 000	73 000
Kuugagwika	Nyari	Oct 95	280 881	322 846	322 846	0
Gatagati	Nyeri	Oct 95	184 800	210 660	120 000	90 660
TaaUta	Makueni	Dec 95	57 975	66 092	66 092	0
Wuumisyo	Makueni	Dec 95	51 018	58 161	61 222	0
Kikalini	Makueni	Dec 95	55 656	63 448	63 067	381
Nzyawa	Makueni	Dac 95	57 975	66 092	66 092	0
Muuo	Makueni	Dec 95	46 056	52 504	55 267	0
Kilome	Makueni	Mar 96	32 112	37 620	28 840	8 986
Kwaseu	Makueni	Apr 96	28 625	34 194	34 931	0
Munyaka	Kirinyaga	May 96	216 000	246 240	218 025	28 215
Mbuani	Kirinyaga	May 96	216 000	246 240	227 941	18 299
Mugumo	Kirinyaga	June 96	180 000	205 200	215 826	0
Gitaga	Kirinyaga	June 96	240 000	273 600	222 874	50 728
TeaUta	Makueni	July 96	30 400	34 656	0	
Gitero	Laikipia	July 96	112 762	128 549	0	128 549
Kahuhoi	Nyeri	Nov 98	210 000	239 400	0	239 400
Kabati	Nyeri	Nov 96	99 890	114 000	0	114 000
Kuuga na g	Nyeri	Nov 95	191 519	209 502	88 025	121 477
TOTAL			8 078 130	9 422 779	6 555 881	2 900 467

TABLE 4
Achievements of zero grazing programme

Project	District	Date disbursed	Amount disbursed	Amount payable	Amount repaid	Balance
Mugira 1	Kirinyaga	May 95	352 000	540 320	139 885	400 435
Muruguru	Nyeri	May 95	442 400	844 250	194 026	650 225
Mugira 2	Kirinyaga	May 95	88 000	135 000	17 009	117 991
Muteitha	Meru	May 95	448 600	626 568	171 900	454 668
TOTAL			1 331 000	2 146 138	522 820	1 623 318

TABLE 5
Progress in ISH programme

Project	District	Date disbursed	Amount disbursed	Amount payable	Amount repaid	Balance
Kwandara	Muranga	Feb 93	917 388	1 408 191	41 664	1 366 527
Kaweru 1	Muranga	Feb 93	699 287	1 073 406		1 073 406
Gura 1	Nyeri	Feb 93	326 189	500 700		500 700
Mwiria 1	Embu	Feb 93	444 656	682 547		682 547
Mwiria 2	Embu	Dec 94	231 299	355 044		355 044
Kuweru 2	Muranga	Dec 94	699 287	1 073 406		1 041 706
Gura 2	Nyeri	Oct 95	213 750	328 106	24 742	303 364
TOTAL			3 531 856	5 421 400	522 820	5 323 294

TABLE 6
Summary of status of projects by SISDO

Programme	Implemented schemes	Final stages of prepration	Initial stages of preparation
Gravity infrastructure	6	6	12
Individual pump-fed and in-field units	37	54	30
Zero Grazing Units	32	20	36
Farm inputs groups in irrigation schemes	54	30	33

Zero grazing programme

This is a new loan programme which arose from the farm inputs programme. The farmers involved in this programme produced large quantities of agricultural by-products. Consequently, high milk yielding cows were identified as a good way to make use of these by-products. The programme is however not restricted to the farm inputs groups. It caters for all smallholder farmers who need cows and whose climatic conditions are suitable for maintaining high grade cows. The status of this programme is given in Table 4.

Many groups are in the preparation stage in Meru, Nyeri, Kirinyaga, Muranga, Embu and Makueni.

Achievements in pump-fed programmes

Four groups, one in Embu, one in Nyeri and two in Muranga, have received credit for pump-fed irrigation systems. The status of this programme is shown in Table 5. A summary of status of projects funded by SISDO is shown in Table 6.

At present SISDO is dealing with 2 200 smallholder farmers who will benefit from the projects. The land area to be utilized by farming groups amounts to 1 700 acres. Loans worth Kshs 25 million have been disbursed.

Training

In February 1996 the Relief Society for Tigray (REST), an Italian Government Organization, requested SISDO to train and expose Ethiopian-funded REST staff to operations of SISDO. Training was successfully conducted both in the classroom and in the field.

IMPACT OF SISDO LOAN PROGRAMMES

SISDO has assisted many groups and in the process it has disbursed Kshs 25 million worth of credit. Seventy-four groups with a total of 1 947 members have received credit, five projects with 600 members have been assisted to install irrigation schemes, seven groups with a membership of 37 families have been assisted to acquire equipment for pump-fed irrigation, 54 groups with 1 277 members received credit for farm inputs, four groups with 96 members received credit to keep high grade cows. Another 4 groups with 44 members received credit for pump-fed irrigation systems.

The farmers assisted have a more reliable supply of food and are earning cash incomes from the sale of their produce. The country is earning foreign currency from export of the horticultural crops grown. Farmers see agriculture as a commercial enterprise and they are able to make rational decisions on what crop to grow, where to market the produce, negotiate marketing and farm inputs supply agreements. They can now have and manage bank accounts. They have developed communal responsibility through the group guarantee network system.

It is currently difficult to quantify the benefits arising from loans disbursed by SISDO. However the following are noteworthy.

Training in commercial agriculture

It is very clear now that smallholder farmers assisted by SISDO view agriculture as a commercial enterprise. They are able to develop cost and income projections and are able to make rational decisions on farming e.g. what crop to grow, where to market the produce, negotiate marketing and farm inputs supply agreements.

Training in financial management

Farmers involved with SISDO are trained in financial management. They are trained in the importance of saving and being self-reliant. Most of the farmers can now handle their own bank accounts. The farmers have also developed communal responsibility through the group guarantee network system.

Creation of cash economy, etc.

SISDO loans are aimed at making agriculture commercial. Where loans were disbursed, farmers have been able to make profits of up to Kshs 45 000 per season from 0.5 acre land portions and loans of Kshs 10 000. Farmers have therefore entered into a cash economy and are now able to purchase items they hitherto could not afford. Indeed farmers state that they are now able to:

- afford proper clothing;
- meet school fees demands better than before;
- start up of other commercial ventures, shops, etc.; and
- buy or get directly from the fields, high value foods, notably vegetables and roots (sweet potatoes in Kirinyaga) and milk for the zero grazing groups.

A review of SISDO activities is necessary to document its successes, note its failures and advise on expansion.

SUSTAINABILITY OF SISDO PROGRAMMES

Before SISDO disburses any loan, beneficiary training is held on the following areas:

- development on cost recovery;
- saving to create development fund; and
- management for operation and maintenance

It is hoped that a group assisted by SISDO will have developed enough savings to finance future developments on its own after 3 years. SISDO would still be available for specialized more capital intensive projects.

Further, SISDO aims at becoming financially independent (able to operate without donor funds) by the year 2000. At this time, the organization aims at developing enough long term loans to generate interest to defray the organizationís operational costs. At the same time projects developed now, will have begun substantial repayments to create enough funds for new developments.

Table 7 shows loan repayments since 1993. The years 1991 and 1992 were formative years while in 1993 SISDO was mainly involved with experimental loans. SISDO requires funds to create a development fund for project funding between now and 2000.

TABLE 7
Loan repayments: 1993 - 1996

Year	Loans disbursed	% repayment	Remarks
1993	3 986 814	30	Mainly experimental loans
1994	1 687 078	73	Start of long-term loans
1995	5 440 966	54	Mainly long-term loans in grace period
1996	13 673 137	31	Mainly long-term loans in grace period

CONSTRAINTS

SISDO has been faced with three main constraints, namely:

i. lack of funds for development purposes;
ii. farmers negative attitude towards credit; and
iii. continued funding through grants for activities which SISDO is funding on credit.

Lack of development funds

SISDO has exhausted its funds available for disbursement, for two main reasons.

- The loan repayment period for irrigation and zero grazing projects is 3-4 years. However, the fund has only been operational for a short period (1.5 years) and as such, repayments to date are not sufficient for disbursement.

- Donor and financial support has not been forthcoming as initially expected.

If further funding is not available immediately, the organization will have to concentrate on recovery of disbursed loans only - more disbursement will not be possible. The Organization requires Kshs 150 million to meet its expected disbursement target in the next 4 years (1997 - 2000), after which funds loaned out to long-term programmes will have become eligible for further lending.

Farmers attitude towards credit for development

Initially there was a negative attitude towards credit for development due to the past experience. At that time all funds came from donors and GoK grants. However, this negative attitude is slowly changing and demand for credit for development is increasing.

Continued funding on grant basis

The government and other NGOs continue to provide grants for activities SISDO is funding through credit. This arrangement creates a misunderstanding as farmers believe that they can wait for grant funding, for example, in the Taita and Taveta Nyambene districts. There is need for clarification of funding policy to remove this misunderstanding.

LESSONS LEARNT

Since SISDO has been in operation, several lessons have been learnt. These include:

- Establishing appropriate interest rates based on costs rather than on philosophical reasons.

- Need to develop appropriate action for dealing with defaulters and fraud by loan staff.

- Need to have impact performance indicators.

- Credit is not only provision of money but also involves equipping borrowers to use it wisely. A loan constitutes a burden and should empower rather than burden the borrower.

- The need to be conscious of gender sensitive issues at the household level as it relates to credit. These issues should be incorporated in training programmes on lending. It is also important to sensitize the private financial sector to these challenges. Innovation and testing of Micro finance must continue as these are unique from community to community.

- The concept of micro credit contradicts the conventional view held by large banking and private sector institutions that collateral is necessary for credit. This concept has been

demonstrated by the numerous requests from various groups for credit. Micro credit goes beyond lending money and includes participation in social transformation.

- Handouts are not the solution to poverty and are a further degradation of mankind; credit provides dignity.
- As opposed to corporate loans, micro credit provides direct advantage to families and communities, by enabling members to take control of their lives rather than depend on charity.
- Most people in developing countries live in poverty and micro credit is a sure way of helping them become independent and self-reliant. This assistance requires capacity building and raising awareness of recipients so that funds can be used properly.

Low-cost irrigation technologies for food security in sub-Saharan Africa

The major bottleneck to increased irrigated food production in sub-Saharan Africa is the lack of low-cost productive technologies. This paper describes low-cost, manual and mechanized irrigation technologies capable of providing considerable production increases to small farmers. The relatively inexpensive and productive nature of these technologies has the potential for increasing the number and the degree to which farmers will participate in the development of the irrigation subsector. While the manual irrigation technologies described herein address the needs of farmers with holdings of 0.5 hectares or less, the mechanized technologies will satisfy the needs of farmers irrigating more than 0.5 ha. The proposed improved technologies will be of interest to farmers already irrigating surface areas in these size ranges by reducing costs as well as those who wish to graduate from smaller farms to larger irrigated areas.

IRRIGATION IN SUB-SAHARAN AFRICA

There are 42 082 000 ha of irrigable land in sub-Saharan Africa of which only about 13 percent, or 5 564 000 ha, is actually under irrigation (FAO, 1995). Development of the irrigation subsector in sub-Saharan Africa has been constrained by the high cost of irrigation schemes constructed until now as well as their management complexity. The investment cost of a full-control irrigation scheme in Niger is US$ 10 000 - 25 000/ha. However, the practice of traditional irrigated agriculture going back several centuries in some arid regions south of the Sahara, the availability of significant water, land, and labour resources in many areas, good and growing domestic and regional export markets for irrigated food crops, and appropriate low-cost manual and mechanized irrigation equipment promise a bright future for the subsector.

Improved irrigation allows for the increased production of many crops. However, sub-Saharan Africa's competitive edge appears to be in the production of high value vegetables and fruits, not such increasingly consumed crops as rice and wheat which can frequently be produced more cheaply elsewhere. As urban populations continue to increase and economic growth rates continue to expand throughout Africa, market prospects are bright for horticultural production. This paper focuses on low-cost technologies for irrigated horticulture as a means of improving food security and increasing small farmer incomes.

The majority of market gardeners in sub-Saharan Africa have farm holdings of less than 0.5 hectares. (The average irrigated surface area in Burkina Faso is 1 063 m^2 (Government of Burkina Faso, 1995), while the average in Cameroon is 565 m^2 among manual irrigators (ATI, 1987)). These farmers will benefit most from improved manual irrigation technologies.

E. Perry
Appropriate Technology International, Washington D.C., USA

In addition, however, a significant portion of vegetable and fruit production is accounted for by larger farmers. These farmers will benefit from low-cost mechanized irrigation technologies. Although these larger farmers are fewer in number than the smaller producers, their contribution to total marketable production may be greater. Smaller farmers, who graduate to larger scale production, will also benefit from mechanized equipment.

IMPROVED MANUAL IRRIGATION TECHNOLOGIES

A number of conditions must be met for successful small-scale irrigated horticultural development to occur: (1) availability of suitable land; (2) availability of water resource; (3) availability of labour; (4) availability of non-irrigation inputs to production; (5) access to markets; (6) capital resources; and (7) appropriate water lifting technology (Norman, 1992; Allen and Perry, 1996). Box 1 provides a general description of the current status of the first six prerequisites for successful irrigated horticulture. However, sustainable development of this potential will require appropriate irrigation equipment, in particular equipment for water lifting. The key attributes of this equipment are:

- greater productivity reflected in higher flow rates relative to traditional water lifting devices; and,
- low capital and recurrent costs and low levels of maintenance.

Three water lifting options are assessed here in the context of Burkina Faso - the traditional rope and bucket method, the motorized pump and the treadle pump. (An assessment of other human powered pumps is not performed here because, as shown elsewhere, they are relatively expensive and poorly suited to use in irrigation due to low output and high human energy requirements (Hyman, 1995)).

Rope and bucket method

Traditional water lifting equipment is usually produced by local artisans using local materials. Examples in West Africa include the chadouf and the rope and bucket. The major advantage of these technologies is their low cost. The major disadvantage of traditional water lifting devices is their low flow rate capacity and resulting small size of irrigated plots which, in turn, limit production and incomes. This technique is very arduous and time consuming, allowing for a flow rate of only about 1 000 litres of water per hour when water is 4.5 metres from ground level. Not unlike most sub-Saharan African countries, approximately 80 percent of horticulturists in Burkina Faso use this type of water lifting system (Government of Burkina Faso, 1995).

Motorized pump

Burkina Faso has experienced a significant increase in the number of motorized pumps in the last 10 years. While there is some limited use of diesel-powered irrigation pumps, the vast majority of these pumps consist of gasoline engines of 2-5 horsepower coupled with a low lift centrifugal pump. The major advantages of motorized pumps are their considerable capacity relative to traditional water lifting means, making it possible to expand irrigated surface areas. Disadvantages include: high capital costs; high recurrent costs; and high maintenance levels.

Since the great majority of users operate their motorized pumps at well below the recommended engine speed in an effort to save on fuel costs, their actual flow rates are far

BOX 1 SIX CONDITIONS FOR SUCCESSFUL SMALL-SCALE IRRIGATED PRODUCTION

In addition to appropriate irrigation technology, a number of conditions must be met for successful small-scale irrigated horticultural development to occur: availability of suitable land, water, and labour resources and non-irrigation inputs to production; access to markets, and capital resources (Norman, 1992; Allen and Perry, 1996).

Availability of Land Resources

A horticultural development programme is justified if it has strong potential for achieving increased production and incomes. Land is one of the most important factors of production linked to this achievement. It must exist in adequate quantities and with the appropriate physical properties for an expansion of irrigated horticultural production to occur.

Experience in several sub-Saharan countries confirms that land availability is not a constraint to increased irrigated production and that resulting increases in irrigated surface area is one of the main contributing factors to successful horticultural development. In Senegal and Mali, where farmers have benefited from improved manual water lifting technologies, gardens have increased in size by an average of 39 percent and 61 percent, respectively (Hyman, 1995; Niembélé and Togola, 1996). In Burkina Faso, farmers using motorized pumps irrigate an average of 2.74 hectares (Gay, 1994). Horticulturists in north Cameroon irrigate an average of 3,178 m^2 when motorized pumps are used, more than five time greater than the surface area irrigated using traditional manual water lifting means (ATI, 1987).

Interviews with individual farmers and representatives of farmer's groups in other African countries have disclosed that while the average manually irrigated garden is usually very small (frequently between 250 m^2 and 1 000 m^2), additional land is available to most farmers for expanded production (Perry, 1996; Perry, 1997).

For productive market gardening to occur suitable soils must exist. Problems can arise if soils are either too sandy or too heavy. Soils that are too sandy may lead to high seepage losses in distribution canals and in basins. Their low moisture retention capacity reduces water available to the crop. If soils are too heavy, the low infiltration rates will cause excessive time for water application (Norman, 1992).

Water Resource Availability

Irrigation of vegetables requires significant quantities of water of suitable quality. To avoid over-expenditure of labour and/or energy, water must be relatively close to the surface, preferably within 0-7 metres. In the case of wells, these must penetrate the water table to sufficient depth and the aquifer must provide adequate recharge to assure necessary quantities of water. Water lifted from surface water sources (e.g. rivers or lakes) must not require a vertical lift greater than 7 metres. Groundwater and surface water having a considerable salt content are not considered to be of suitable quality for irrigation purposes.

Information regarding well volume and recharge rates has been collected in some West African countries. In many cases, low recharge rates require that wells be widened and deepened or their numbers multiplied, if improved, higher capacity water lifting technologies are to be fully utilized (Perry, 1996; Perry, 1997). Minor modifications to the lifting technology (e.g. smaller diameter cylinders in the case of the treadle pump) and ancillary equipment (e.g. wrapped filters), where appropriate, may also be helpful in increasing pumping ease and well flow capacity.

Some horticultural areas suffer from permanent or seasonal water shortages. This shortage, of course, occurs to a greater or lesser extent in all sub-Saharan Africa countries.

Availability of Labour

Traditional irrigated horticulture is a highly labour intensive activity. In Senegal, it is estimated that as much as 80 percent of traditional market gardening labour time is devoted to irrigation-related tasks (i.e. water lifting and distribution). Senegalese horticulturists using manual water lifting and distribution means average more than 7 000 hours for the irrigation of one hectare (Hyman, 1995). In Niger, the labour requirements for manual water lifting (not including water distribution or other non-irrigation activities) from a well over a four-month crop cycle can exceed 6 000 hours per hectare for a single farmer (Norman, 1992). Using the *chadouf*, horticulturists in north Cameroon take approximately 5 800 hours to irrigate one hectare over the same four-month period (ATI, 1987). In Benin, a small sample of market gardeners found average time spent to be in the order of the Niger and Cameroon findings (Perry, 1997).

1 The *chadouf* or counterpoise lift, is used for water lifting from shallow wells (2-6 meters in depth). It consists of a container, sometimes a 10-litre metal can attached to the end of a rope which hangs from a lever with a counterweight on the other end. Using the concept of mechanical advantage, the weight may be sufficient to balance between one-half and the entire weight of the full can so that the operator need only lift up to one-half of the combined can and water weight. To return the receptacle to the water source, the operator uses at least some of his/her weight to tip the counterweight in order to pull the lever down. The weight of the counterweight depends on the lift, terrain, and operator's liking.

Given the availability of land during the dry season for the expansion of irrigated farming, it is anticipated that the introduction of an improved water lifting technology will lead to larger irrigated surface areas. The labour saved by the using the new lifting device can be applied to increase the amount of hectarage under cultivation. This increase in irrigated area has occurred in Senegal with the introduction of improved manual water lifting equipment (Hyman, 1995). In north Cameroon, farmers using motor-driven centrifugal pumps and irrigating approximately 3 200 m^2 employ an average of 2.8 persons, while manual irrigators employ 2.1 persons (ATI, 1987). On balance, it is not expected that the number of farm workers will significantly decrease or increase. However, in some cases, these larger surface areas may require greater numbers of workers.

Availability of Non-Irrigation Inputs

While by no means optimal, the availability of non-irrigation inputs is not, in most cases, the major obstacle to the development of the small-scale irrigated horticulture. In general, although used in relatively limited amounts in most locations in sub-Saharan Africa, non-irrigation production inputs (e.g. seeds, fertilizer, and pesticide) are generally available locally and in sufficient quantities to allow for expanded horticulture production. Increased availability will be driven by increased producer demand for such inputs.

Access to Markets

Market outlets for vegetable and fruit production are imperative for successful small-scale irrigated horticulture to occur. Relative proximity and reliable physical linkages to a market must exist.

Regardless of the other investments made in the subsector, horticulturists will require expanding markets to increase their incomes. Without a sufficient market for vegetables and fruits, increased market garden production will not have the desired effect of increasing producer household incomes. Based on the growing numbers of newly active market gardeners in all of the West African countries, apparently attracted by the prospects of higher incomes, the subsectoral outlook has been good in recent years in that part of sub-Saharan Africa. The future potential for an expanded market for vegetables and fruits will depend on three factors: increased local demand; increased substitution of locally produced fruits and vegetables for imported produce and increased exports.

Given the highly competitive, quality sensitive nature of the European markets, the best promise in the near future (or short term) for expanded commercialization of West African vegetables and fruits resides in the domestic and, to a lesser degree, in the regional market. The trend whereby urban dwellers in West Africa have in recent years increased their consumption of vegetables and fruits has been noted by informed observers. Even the local market potential has been strengthened in some countries as the same tendency has also been observed in the rural sector. In recent years, as vegetable and fruit consuming urban populations in West Africa have grown in size and as consumer tastes, rural as well as urban, have changed to incorporate greater amounts of vegetables and fruits in the diet, local demand has expanded. As the phenomena of increasing urban populations and changing tastes persist, continued growth in domestic demand is anticipated.

In general, interventions that extend the agricultural calender (e.g. improved low-cost water lifting and accessing technologies) and allow for the storage and/or the processing of fresh produce may help to further improve the market outlook for vegetable and fruit production. However, countries where consumers have only recently acquired a taste for some fresh fruits and vegetables, the widespread consumer acceptance of processed agricultural products is still to be market-proven and is likely to take another generation before it becomes established.

Access to Capital

Financial capital can be important to the expansion of horticultural production. However, this variable should not be over-emphasized in the case of small producers who require relatively small amounts of capital. A sample of horticulturists (both traditional manual and mechanized irrigators) in Benin revealed average annual cash expenses, not including hired labour, of US$ 329 per hectare (Perry, 1997). This expenditure compares to Côte d'Ivoire, where non-labour inputs for the production of one hectare of onions costs US $256 (Government of Benin, 1995b). While not insignificant, these costs are bearable by active commercial horticulturists.

Income earned from irrigated horticultural production is well above the earnings of the average West African farmer. Four Beninese small-scale horticulturists surveyed reported an average annual net income of US$ 691 (Extrapolated to a uniform irrigated surface area, one hectare of irrigated vegetables yields an annual net income of US$1 870) (Perry, 1997). Unlike the situation of traditional farmers practising rainfed agriculture, where there is little or no cash income, this revenue makes new investments in the horticultural subsector much more feasible, and makes less necessary recourse to formal financial institutions.

from the rated capacities. Gay (1994) found that the actual capacities averaged from 5.2 m^3 per hour to 11.3-15.6 m^3 per hour, depending on whether installation occurs at a well site or a surface water source. This is a significant finding, indicating that in some instances (e.g., water lifting from wells) high performance manual technologies can compete favourably with motorized pumps in the critical area of flow rate capacity.

Treadle pump

The treadle pump originated in Bangladesh in the early 1980s. In late 1990 and mid-1995, commercial dissemination began in Senegal and in Mali, respectively. By the end of December 1996, twenty-five manufacturers in Senegal had produced and sold more than 1 900 pumps, while ten such producers in Mali had sold approximately 600.

The treadle pump has a number of features which set it apart from other manual irrigation pumps. The standard version can lift 5 000 to 7 000 litres of water an hour from wells, boreholes or surface water sources for a suction head of up to 7 metres. Because the pump employs the user's body weight and leg muscles, it is much less tiring than other manual pumps that utilize the upper body and arm muscles. Fabricated from locally available materials, it can be manufactured by metal working shops equipped with welders and simple hand tools such as those frequently found in large numbers in sub-Saharan African capitals and many secondary towns.

At a lift of 4.5 metres, the treadle pump has a discharge of 1.7 l/sec. It can be made for approximately CFAF 63 000 [1] in Burkina Faso. Drawing water from a surface water source or from a well with sufficient capacity, this pump can irrigate an area of approximately one-half hectare. Table 1 summarizes the performance parameters and initial investment cost of the rope and bucket technology, the treadle pump, and a locally available motorized pump.

TABLE 1
Comparisons of alternative water lifting technologies

Water lifting device	Capacity at 4.5 m (l/sec)	Initial cost (CFAF)	Depth range (m)
Rope end bucket	0.3	5 000	0 - 7
Treadle pump	1.7	63 000	0 - 7
Motorized pump	2.1	361 000	0 - 7

A major constraint to increased irrigated crop production in Burkina Faso is low water lifting and distribution capacity. Any pump supplying significantly greater flow rates relative to the traditional rope and bucket system will increase irrigated surface areas and reduce irrigation labour time relative to the original irrigated surface area, resulting in increased production (Hyman, 1995 and Gay, 1994).

The question then becomes which improved method, the treadle pump or the motorized pump, is most cost-effective within the range of surface areas achievable by the treadle pump (i.e. 0.5 ha or less). Assuming that both the treadle pump and a motorized pump will result in similar production increases in that range of surface areas attainable by the treadle pump and that, except for water costs, the cost of inputs are the same for both improved methods, a

[1] Five hundred CFAF are roughly equivalent to US$ 1.

BOX 2 COMPARATIVE COSTS OF WATER PUMPED USING A TREADLE PUMP AND A GASOLINE-POWERED PUMP: THE CASE OF BURKINA FASO

This comparison of pumping costs using the treadle pump and a small motorized pump available in Burkina Faso is based on the assumptions cited below for market gardens of 0.50 hectare.

Key general assumptions on the performance of this comparative cost analysis are:

- 80 m^3 of water are required per hectare per day, or 40 m^3 per 0.50 hectare;
- 180 days of irrigation are required per year;
- 14 400 m^3 are required annually per hectare, or 7 200 m^3 per 0.50 hectares.

Treadle Pump Assumptions

- The treadle pump is operated by two people and delivers 6 m^3 per hour. While one person pumps, the other is directing the flow of the water to different sections of the field. Therefore, 6.6 hours of labour are needed for two persons at CFAF 63 per person-hour. The total labour cost is CFAF 840, or CFAF 21 per cubic metre.
- The treadle pump and 27 metres of PVC pipe cost a total of CFAF 85 500 and have an expected lifetime of 6 years. Therefore, given an annual depreciation of CFAF 14 250 and 7 200 m^3 of water pumped annually, the depreciation cost per cubic metre is CFAF 2.
- It is estimated that spare parts and repairs will cost CFAF 3 500, or CFAF 0.5/m^3, and lubricant CFAF 13 500 per year, or CFAF 1.9/m^3. Therefore, spare parts, repairs and lubricant will cost CFAF 2.4/m^3.

Motorized Pump Assumptions

- The Barbara pump with a capacity of 7.5 m^3 per hour is operated by one person. Virtually all of the person's time is spent directing the water being pumped to different parts of the field being irrigated. Therefore, 5.3 hours of labour are needed for one person at CFAF 63 per person-hour. The total labour cost is CFAF 334, or CFAF 8.4 per cubic metre.
- The motorized pump, 7 meters of suction hose and 20 meters of delivery hose will cost a total of CFAF 361 000 and have an expected lifetime of 5 years. Therefore, given an annual depreciation of CFAF 72 200 and 7 200 m^3 of water pumped annually, the depreciation cost per cubic meter is CFAF 10.
- Spare parts and repairs cost CFAF 50 000 a year, or CFAF 6.9 per cubic metre.
- The motorized pump will consume 0.4 litres of gasoline per hour at CFAF 390 /litre for 5.3 hours a day. Therefore, CFAF 827 is spent daily, or CFAF 20.7 per cubic metre.
- Lubricating oil is consumed at a rate of 1 litre per 20 hours of pump operation at CFAF 1 438/litre, that is, CFAF 381 per day, or CFAF 9.5 per cubic metre.

determination has been made within the context of Burkina Faso as to whether the treadle pump or the motorized pump produces the least costly water supply, maximizing to the greatest degree the net income of the market gardening enterprise (see Box 2 for general and pump-specific assumptions).

The total cost for a cubic metre of water to irrigate 0.5 hectares is significantly greater with a motorized pump than with a treadle pump. Instead of a total expenditure of CFAF 55.5/m^3, the cost of a cubic metre of water is CFAF 25.4 when the treadle pump is used. Therefore, use of the treadle pump will save CFAF 216 720 per year relative to the motorized pump, generating a signi-ficant increase in net income.

These same comparisons can be made for 0.33 hectares. At one-third of a hectare the cubic metre cost difference is even greater (see Table 2).

Manual groundwater development

TABLE 2

Comparative cost of one cubic metre of water for the treadle pump and a motorized pump and for different surface areas

Costs	TP (0.33 ha)	TP (0.5 ha)	MP (0.33 ha)	MP (0.5 ha)
Labour	21	21	8.4	8.4
Deprec.				
3 years				
4 years				
5 years				10
6 years		2	12.7	
7 years	2.6			
Spare parts & repairs	0.5	0.5	6.9	6.9
Lubric.	1.9	1.9	9.5	9.5
Fuel	0	0	20.7	20.7
TOTAL	26.0	25.4	58.2	55.5

TP = Treadle Pump
MP = Motorized Pump

The hand augured tubewell, a low-cost water source for small farmers, has been widely disseminated in Niger and to a lesser extent in some other West African countries (e.g. Benin, Nigeria, Senegal and Mali). This technology is inexpensive and quickly installed. In Benin the hand augured tubewell costs as little as US$ 30 for a ten-foot deep well. Working in teams of two workers, two such tubewells can be installed daily. Depending on the aquifer and soil conditions, hand augured tubewells can yield up to 14 cubic metres of water per hour.

Other manual methods, such as the sludger technique, which have gained widespread acceptance in Asia, have had less success in Africa due probably to the less favourable hydrological and soil conditions found where it has been tried. Nevertheless, these techniques deserve greater consideration in sub-Saharan Africa's efforts to develop the irrigation subsector.

MECHANIZED TECHNOLOGIES FOR SMALL-SCALE IRRIGATION

Some sub-Saharan African countries (e.g. Niger, Nigeria, Zimbabwe, and Cameroon) possess large areas of land having shallow aquifers recharged by seasonal rainfall and flooding. While some areas exhibit low recharge rates only appropriate for traditional lifting of water or improved manual technologies, such as the treadle pump, in many locations hand-dug lined wells or tubewells inserted into these shallow aquifers will yield sufficient water for higher discharge mechanized pumps. These same high-capacity mechanized pumps are appropriate to surface water sources found in many African countries. There are two main areas where mechanized technologies can improve the efficiency of small-scale irrigation: water lifting and groundwater development. Improved water distribution technologies will also help to lower the cost of irrigation water.

Mechanized water lifting

Mechanized water lifting has been plagued by a number of technical problems in sub-Saharan Africa. These problems include high investment and operating costs, limited suction head, and seasonal, as opposed to year around, usage.

The author is grateful to Carl Bielenberg for his contribution to this section of the paper.

High Investment Cost. Low per caput income of sub-Saharan African farmers limits their ability to procure relatively expensive pumpsets of European and Japanese manufacture which comprise all of the motorized pumps in use in many countries (Gay, 1994). Low purchasing power has played an even greater role as regards the more expensive diesel pumpsets which have a longer life and lower operating costs per cubic metre of water pumped than the relatively inexpensive gasoline engine-powered pumps. Diesel engine-powered pumps sold in West Africa cost between US$ 3 200 and US$ 12 000, depending on pumping capacity. According to their power rating, gasoline engine-powered pumps marketed in West Africa tend to cost between US$ 700 and US$ 900.

Imported diesel-powered centrifugal pumps from Chinese and Indian manufacturers as well as locally produced axial flow pumps provide low investment cost options for horticulturists and rice farmers who require large amounts of irrigation water.

TABLE 3
Relative cost of fuels useable in irrigation in Niger

	Price per litre (in CFA francs)	Percent of cost of gasoline
Kerosene	130	42
Diesel Fuel	205	66
Gasoline	310 (375 for super not used for irrigation)	100

High Operating Cost. High operating costs, in particular the cost of fuel, reduces the profitability of many mechanized pumps in use in West Africa. The cost of pumped irrigation water in Niger using a gasoline-powered pump is 30-50% of the total pump operating cost (Gay, 1994). Therefore, operating costs will be lower for motors that use less expensive fuels. In Niger, the most expensive engine fuel is gasoline, followed by diesel fuel, and kerosene. Kerosene and diesel fuel are 42 and 66%, respectively, of the cost of gasoline (Table 3). The price differentials are representative of many other West African countries.

Relatively low-cost fuels, including kerosene for spark ignition engines, diesel fuel for diesel engines and locally produced plant oil as a diesel fuel substitute in diesel engines have the potential for significantly reducing the costs of pump operation. Taking the case of Niger, Box 3 assesses the comparative cost of water using these alternative fuels.

Limited Suction Head. The vast majority of mechanized pumps used in sub-Saharan Africa are motorized centrifugal pumps. One of the drawbacks to this technology is that the suction lift is theoretically limited to 6-7 metres. In Niger a survey of motorized farmers around Maradi found that the net suction head is actually between 2 and 5 metres (Gay, 1994). At these relatively shallow depths the recharge rate will not be as high as it is at greater heads. Low recharge rates will limit the potential for irrigated agriculture and increase the pumping cost as pump users choose to run the engine at slower than optimal speed to better match the pump's discharge capacity with the well's recharge rate, thereby increasing fuel consumption per cubic metre of water pumped. Established farms cannot grow as much as they might, and some areas will never develop irrigated agriculture at all because the aquifer is too deep to be tapped by standard centrifugal pumps.

Low-cost jet pumps in conjunction with centrifugal pumps have the potential for lifting water from aquifers up to 30 metres in depth. The potential for immediate impact is considerable. Not only would new mechanized farmers be interested in such technology, but hundreds, perhaps thousands, of farmers who are already using centrifugal pumps would have the opportunity, at very low incremental cost (approximately US$ 50 per unit, if produced locally) to expand surface areas under irrigation by pumping deeper, more abundant groundwater.

BOX 3: COMPARATIVE COSTS OF WATER PUMPED USING MECHANIZED MEANS:
THE CASE OF NIGER

Of primary importance in the selection of mechanized water lifting devices is the relative cost of the water pumped. This appendix compares gasoline-powered pumps with kerosene-powered pumps for 1 and 2 hectares; and, gasoline-powered pumps with Chinese-made diesel-powered pumps for 3 and 4 hectares. The data presented here are specific to Niger.

General Assumptions

Key general assumptions in the performance of this comparative cost analysis are:

- 80 m^3 of water are required per hectare per day;
- 180 days of irrigation are required per year; and,
- 14 400 m^3 are required annually per hectare.

Gasoline-Powered Pump Assumptions

- The gasoline-powered pump with a capacity of 20 m^3 per hour is operated by one person. Virtually all of the person's time is spent directing the water being pumped to different parts of the field being irrigated. Therefore, 4 hours of labour are needed for one person at CFAF 63 per person-hour. The total labour cost is CFAF 252 or CFAF 3.2 per cubic metre.
- The gasoline-powered pump and 7 metres of suction hose and 20 metres of delivery hose will cost a total of CFAF 450 000 and have an expected lifetime of 5 years. Therefore, given an annual depreciation of CFAF 90 000 and 14 400 m^3 of water pumped annually, the depreciation cost per cubic metre is CFAF 6.3.
- Spare parts and repairs cost CFAF 50,000 a year, or CFAF 3.5 per cubic metre.
- The gasoline-powered pump will consume 0.5 litres of gasoline per hour at CFAF 310/litre for 4 hours a day. Therefore, CFAF 620 is spent daily, or CFAF 7.8 per cubic metre.
- Lubricating oil is consumed at a rate of 1 litre per 50 hours of pump operation at CFAF 1 400/litre, that is, CFAF 112 per day, or CFAF 1.4 per cubic metre.

Kerosene-Powered Pump Assumptions

- The kerosene-powered pump is operated by one person and delivers 20 m^3 per hour. Therefore, as in the case of the gasoline engine, 4 hours of labour are needed for one person at CFAF 63 per person-hour. The total labour cost is CFAF 252 or CFAF 3.2 per cubic metre.
- The kerosene-powered pump costs approximately CFAF 500 000 and has an expected lifetime of 4.5 years. Therefore, given an annual depreciation of CFAF 100 000 and 14 400 m^3 of water pumped annually, the depreciation cost per cubic meter is CFAF 6.9.
- It is estimated that annual spare parts and repairs will cost CFAF 50 000, or CFAF 3.5/m^3.
- The kerosene-powered pump will consume 0.4 litres of kerosene per hour at CFAF 130/litre for 4 hours a day. Therefore, CFAF 208 is spent daily, or CFAF 2.8 per cubic metre.
- Lubricating oil is consumed at a rate of 1 litre per 50 hours of pump operation at CFAF 1 400/litre, that is, CFAF 112 per day, or CFAF 1.4 per cubic metre.

The total cost for a cubic metre of water for the irrigation of one hectare is greater with a gasoline-powered pump than when a kerosene-powered pump is used. Instead of a total expenditure of CFAF 22.2/m^3, the cost of a cubic metre of water is CFAF 18.4/m^3 when the kerosene-powered pump is used. Therefore, use of the kerosene pump will save more than CFAF 246 000 over the 4.5-year life of the pump. Fuel savings will total almost CFAF 75 000 in Year 1 and CFAF 374 400 over the life of the pump. Use of the kerosene-powered pump to irrigate 2 ha will generate CFAF 397 400 over the 3-year life of the pump.

Diesel-Powered Pump Assumptions

- The diesel-powered pump is operated by one person and delivers 40 m^3 per hour. Therefore, to allow for the irrigation of 3 hectares, 6 hours of labour are needed for one person at CFAF 63 per person-hour. The total labour cost is CFAF 378 or CFAF 1.8 per cubic metre.
- The diesel-powered pump costs approximately CFAF 1 000 000 and has an expected lifetime of 8 years. Therefore, given an annual depreciation of CFAF 125 000 and 43 200 m^3 of water pumped annually, the depreciation cost per cubic meter is CFAF 2.9.
- It is estimated that annual spare parts and repairs will cost CFAF 62 500, or CFAF 1.4/m^3.
- The diesel-powered pump will consume 1.2 litres of diesel fuel per hour at CFAF 205/litre for 6 hours a day. Therefore, CFAF 1 476 is spent daily, or CFAF 6.2 per cubic metre.
- Lubricating oil is consumed at a rate of 3 litres per 100 hours of pump operation at CFAF 1 400/litre, that is, CFAF 252 per day, or CFAF 1.1 per cubic metre.

The cost of one cubic metre of water for the irrigation of 3 hectares is CFAF 25.8 when a gasoline-powered engine is used. This compares with CFAF 13.2 when a diesel-powered pump is employed, saving CFAF 12.6 relative to the gasoline engine. Therefore, a total of CFAF 544 320 is saved by using a diesel-powered engine to irrigate 3 hectares, CFAF 4 354 500 over the 8-year life of the pump. Irrigation of 4 hectares using a diesel-powered engine will save CFAF 725 700 during Year 1 of use, CFAF 5 080 000 during its 7-year life.

TABLE 4
Cost of one cubic metre of water for different pumps and for different surface areas

Costs	GP (1 ha)	KP (1 ha)	GP (2 ha)	KP (2 ha)	GP (3 ha)	DP (3 ha)	GP (4 ha)	DP (4 ha)
Labour	3.2	3.2	3.2	3.2	3.2	1.6	3.2	1.6
Deprec.								
1 year					10.4		10.4	
2 years								
3 years			5.2	5.8				
4 years								
4.5 yrs		7 7						
5 years	6.3							
6 years								
7 years								2.5
8 years						2.9		
Spare parts & repairs	3.5	3.5	2.8	2.8	4 6	1.4	4.3	1.2
Lubric.	1.4	1.4	1.4	1.4	1.4	1.1	1.4	1.1
Fuel	7.8	2.6	7.8	2.6	6.2	6.2	7.8	6.2
TOTAL	22.2	18.4	20.4	15.8	25.8	13.2	27.1	12.6

GP = Gasoline-Powered Pump; KP = Kerosene-Powered Pump; DP = Diesel-Powered Pump

Seasonal Usage. Mechanized irrigation pumps are rarely used at other times of the year than the annual dry season. Pump operating costs can be reduced by using pumpsets for applications other than irrigation. Both centrifugal and axial flow pumps can very easily and inexpensively be adapted for boat propulsion, using a design found widely in Asia that makes river travel possible, even when water depths in the river are only 1-2 metres. In Sudano-Sahelian West Africa this use is compatible with their use for irrigation as river navigation is most practicable from the end of the rainy season (August-September) until the end of the year, while irrigation is primarily practised from November/December through April. Boat-mounted pumpsets will greatly enhance transportation on the rivers, improving produce marketing in countries where transport infrastructure is underdeveloped, and will allow the pump/boat owner to contract with a number of farmers located along the banks of the river to supply them with irrigation water.

There is a wide range of mechanized water lifting technologies which have been developed around the world. These pumps have varying capacities, capabilities and costs. A number of these technologies have promise in sub-Saharan Africa for increasing the efficiency of irrigation water use. They include: kerosene-fueled centrifugal pumps; low-cost diesel-powered centrifugal pumps; water lifting using venturi ejectors with conventional centrifugal pumps; river-based low head and ultra low head irrigation pumps; and use of vegetable oils as a diesel fuel substitute in diesel powered centrifugal pumps (see Boxes 4 and 5).

Mechanized groundwater development

Another major obstacle to increased irrigation capacity is the cost of accessing adequate quantities of water for the purpose of irrigation. In Senegal and Botswana, a technology called the "wrapped filter" (also referred to as a "well-point") has been developed to improve the recharge rate of lined and unlined hand dug wells. This low-cost technology is essentially a short washbore injected into the floor of the well using a motorized pump and into which the intake hose from the pump is then inserted for water lifting purposes. The "wrapped filter" significantly increases the recharge rate of wide-diameter wells, doubling the availability of water for irrigation purposes. Based on a small sample of farmers using the wrapped filter in Senegal, this technology has made it possible to more than double the irrigated surface area.

BOX 4: PROPOSED MECHANIZED WATER LIFTING DEVICES

Kerosene-Powered Centrifugal Pumps

Depending on pump capacity, irrigation practices and engine fuel consumption, it is estimated that 30-50 percent of the cost of irrigation water can be attributed to fuel cost (Gay, 1994). Kerosene-powered spark ignition engines would enable small farmers to avoid the high cost of gasoline, which is frequently heavily taxed, using less expensive kerosene instead. Kerosene in Niger for example is approximately 40 percent of the cost of gasoline. Kerosene-powered engines are essentially the same as gasoline-powered, but are started on gasoline using one of two tanks and switched to the tank containing kerosene after warm up. The engines are slightly modified to provide the optimal compression ratio for burning kerosene. Small, lightweight kerosene-fueled engines are made by Fuji Heavy Industries of Japan, but may also be available from India and China. They cost only slightly more than gasoline-powered engines of the same horsepower. Kerosene-fueled engines have been widely used in some African countries, including the Central African Republic, where they operate maize and cassava grinding mills. In addition to its relatively low price, another major advantage of kerosene compared to gasoline is its convenient availability in many village settings. There are two main disadvantages of kerosene use: greater carbon deposits, necessitating more frequent engine cleaning and increased contamination of the crankcase lubricating oil, requiring more frequent crankcase oil changes to avoid shorter engine service life. The cost of water calculations account for these factors by assuming a shortened service life of 4.5 years. Improvement in engine maintenance could be achieved through appropriate training of project technical staff, merchants and manufacturers.

Low-Cost Diesel-Powered Centrifugal Pumps

In combination with low-cost tubewells, locally manufactured diesel pumpsets have helped make India and China the countries with the most irrigated surface area in the world. (In 1990, India's net irrigated area was 43 050 000 hectares, an increase of more than 20 million hectares since 1950.) Diesel-powered pumps are significantly heavier and more expensive than gasoline- or kerosene-powered units of the same capacity. However, diesel engines, if well made and properly serviced, are much longer lasting than spark ignition engines and use less fuel per cubic meter of pumped water. A project to promote diesel-powered pumps should pre-select small well made, affordable and adapted diesel engines and diesel powered pumps from India and China. In addition to the price, quality, and adaptability of their products, selected manufacturers from these Asian countries should also have experience exporting their products to Africa. Given the importance of maintenance to the longevity of diesel-powered pumps, added emphasis should also be given to this criterion during training of project staff, merchants, and manufacturers.

River-Based Low Head and Ultra Low Head Irrigation Pumps

River-based irrigation should focus on major rivers and their tributaries, and should utilize technologies which reduce pumping costs by reducing the initial cost of the pumping equipment, by encouraging multiple usage of irrigation pumps and contract irrigation, and by promoting low-cost fuels.

Low head pumps will be similar to the centrifugal pumpsets described above. Such pumps will be of small (5-10 horsepower), single cylinder as well as medium (10-40 horsepower) multicylinder design.

Ultra low head technologies will consist of locally made axial flow (propeller) pumps driven by similar or identical single and multicylinder engines. While centrifugal pumps are able to operate against lifts of 30 metres, propeller pumps work efficiently at up to 5 metres lift, but provide a much larger flow. These pumps propel water by the reaction to lift forces produced by rotating its blades. This action pushes the water past the impeller while imparting a spin to the water which passes through fixed guide vanes to straighten the flow and convert the spin component of velocity into extra pressure. A portable, high capacity axial flow pump capable of delivering 100-200 m^3 at heads in the range 1-5 metres is recommended. The International Rice Research Institute (IRRI) has developed such a pump requiring a 5 hp engine capable of driving a 3.7 meter shaft at 3 000 rpm to discharge water through a 150 mm delivery tube. The IRRI axial flow pump can be manufactured in small machine shops.

Such axial flow pumps can be so constructed to allow the owner to easily disconnect the engine and the propeller from the water pumping unit so that the engine/propeller unit can drive a boat transporting goods and passengers. Alternatively, axial flow pump owners could perform contract irrigation along water courses, stopping their boats along the banks of the river to use the boat propeller and shaft to irrigate rice paddies or vegetable fields. This system is used extensively in Southeast Asia to irrigate thousands of hectares of land and for river transport.

Water Lifting from Aquifers of Medium Depth Using Venturi Ejectors with Conventional Centrifugal Pumps

Centrifugal pumps have a maximum suction lift of 6-7 metres and are often difficult to prime at more than 5 metres suction lift. Conventional centrifugal pumps can be made to lift water from much greater depth by the addition of a low-cost venturi ejector. The combination of a centrifugal pump and a venturi ejector is commonly referred to as a jet pump. Electrically operated jet pumps supply water to many homes in the United States having wells up to 30 metres deep. It is recommended that low-cost gasoline, kerosene, and diesel powered jet pumps for small-scale irrigation from aquifers up to 30 metres deep be field tested. Jet pumps installed in tubewells of 100 mm diameter should be capable of lifting up to 15 m^3 of water per hour at a depth of 30 metres, or up to 40 m^3 per hour from 150 mm diameter wells. Open wells can accommodate larger venturi ejectors providing greater flows.

BOX 5: ALTERNATIVE FUELS FOR DIESEL-POWERED PUMPS

Vegetable Oils as a Diesel Engine Fuel

ATI, in collaboration with the Better World Workshop in Vermont, is testing inexpensive diesel engines using jatropha curcas oil as a fuel. Jatropha curcas is a small tree that grows wild or is planted for live fencing by small farmers in much of sub-Saharan Africa. Jatropha curcas seeds are not edible, and therefore is not usually harvested by farmers. The seed contains about 35 percent inedible oil by weight, which can be easily extracted using simple manual presses or motorized expellers. Jatropha oil burns very well in diesel engines of the prechamber or swirl chamber type, producing nearly the same work output as when run on diesel fuel.

BOX 6: MECHANIZED DEVICES FOR IRRIGATION WATER DEVELOPMENT

Well Jetting

Well jetting is a low-cost technique for establishing small diameter wells (50-160 mm) using the force of water to cut directly into the ground, liquefy the soil, and allow the insertion of riser pipe or well screens. The applicability of well jetting and the modification of the technique that has to be used where it is applicable depend on the nature of the soil above the aquifer, the depth of the aquifer, and the grade of sand in the aquifer.

In northern Nigeria, well jetting has been used with temporary casings to install over 5 000 new wells in just a few hours per well in places with 3-4 m of heavy soil overburden. By contrast, it can take three days to construct a well using manual techniques. Highly favorable conditions over extensive areas in the southern part of the country, very similar to those that exist in northern Nigeria, could allow well jetting to flourish in Niger. In these areas, coarse sand is under pressure and former river beds have formed very permeable aquifers.

Wrapped Screens

The ability of some farmers to expand their irrigated area or provide crops with a larger amount of water is sometimes limited by insufficient water availability due to low well recharge rates. In Senegal it has been found that hand-dug, cement-lined wells typically have overnight recharge rates of 3-4 m^3 of water and this amount can easily be pumped out in less than an hour. Deepening cement-lined wells by adding cement rings is time consuming, expensive, and might allow more fine sand to enter the well -- reducing the well's capacity and water quality. In addition, as in the case of newly constructed hand-dug wells, deepening a well using traditional methods is dangerous. The wrapped filter reduces this risk. The installation of a wrapped screen in a short borehole at the bottom of an existing cement-lined well is a cost-effective alternative for farmers in areas with sandy soil and low well recharge rates. Although results might differ depending on local conditions, field tests conducted in Senegal in 1994 found that well recharge rate increased by 100 percent following installation of the wrapped filter.

Most water enters artesian wells from the bottom and a wrapped screen increases the recharge rate significantly by expanding the surface area for collection of water. Without the wrapped screen, the only benefit market gardeners with limited water availability would gain from an improved manual water lifting device or mechanized pump over the traditional system would be the labour time savings in lifting water because they lack the additional water needed for expanding production.

Wrapped screens are made of PVC tubing with drilled perforations wrapped with a single outer layer of permeable fabric (usually locally purchased woven polyester) that is stitched around the entire circumference of the screen to prevent sand from entering the PVC cylinder and clogging it. Once drilled and wrapped, the wrapped screen is driven into the bottom of a well by water pressure applied through a PVC pipe using a motorized pump. For installation, the wrapped screen is attached to the end pipe of the pump where water normally comes out. PVC pipe is also used to connect water in a cement basin to the pump's water intake pipe. Water is then pumped into the ground from the basin and the force of pumping drills the borehole. The cost to the farmer is approximately US$ 60.

Another water accessing technique, a motorized washbore method of installing tubewells, is capable of releasing significant quantities of water at low cost. It has very good potential in countries where the hydrological and subsoil conditions are appropriate (i.e. coarse sand and good recharge rates). In Northern Nigeria these tubewells number in the thousands. Very good potential exists in parts of Niger, Cameroon, Benin and possibly Zimbabwe, Botswana and Ghana.

Both the wrapped filter and the washbore techniques allow for rapid installation and are low cost. The introduction of these water development technologies also complement the use of mechanized irrigation pumps that sometimes cause the collapse of the sides of traditional wells. The more resistant PVC wall of the wrapped filter and the washbore will prevent this potentially dangerous and costly situation from occurring (see Box 6 for a more detailed description of the wrapped filter and washbore technologies).

Water distribution technologies

The cost of irrigation water lifted using mechanized means is increased due to inefficient water distribution methods (frequently unlined canals that permit water losses through seepage) and/or the high cost of reinforced distribution hose. Improved, inexpensive water distribution technologies will lower the unit cost of irrigation water. Promising low-cost techniques include lined canals, light weight plasticized hose, drip irrigation (using PVC pipe instead of more expensive materials), PVC pipe, and thin-walled water holding tanks. These and other technologies will be considered for testing, bearing in mind the need to keep these products low in cost and affordable to small farmers and adapted to local conditions. PVC pipe and holding tanks have been tested and promoted by ATI in Senegal. Low-cost holding tanks have proven to be well adapted to the sandy soil conditions encountered in Senegal and other parts of West Africa. PVC pipe is used in both Senegal and Mali as a low-cost solution to water distribution.

Conclusion

There are hundreds of thousands of small farmers practising irrigated agriculture in sub-Saharan Africa. The technologies described herein are capable of assisting them to increase production, resulting in greater incomes and increased food security. The low cost of the proposed technologies relative to currently available equipment will facilitate acquisition. Reduced operating costs will make use more sustainable. Because some of the proposed equipment (i.e. treadle pump, axial flow pump, venturi ejector, and all of the various tubewells) can be produced locally, there will be strong linkages to the manufacturing sector that will create some employment and increase the income of manufacturers.

References

Appropriate Technology International. 1987. *Treadle Pump Project Plan*. Washington, D.C. Appropriate Technology International.

Allen, H. and Perry, E. 1996. *Human Powered Irrigation for Smallholders: Approach to Implementation*. Addis Ababa: CARE International and Appropriate Technology International.

FAO. 1995. *Irrigation in Africa in Figures*. FAO, Rome.

Gay, B. 1994. *Irrigation Privée et Petites Motopompes au Burkina Faso et au Niger*. Paris: Groupe de Recherches et d'Echanges Techniques.

Government of Benin, Ministry of Rural Development. 1995a. *Filière piment*. Cotonou: Government of Benin.

Government of Benin, Ministry of Rural Development. 1995b. *Schémas de relance des filière de pomme de terre et d'oignon*. Cotonou: Government of Benin.

Government of Burkina Faso, Ministry of Agriculture and Animal Resources. 1995. *Enquête maraîchère campagne 1994/95 (résultats préliminaires)*. Ouagadougou: Government of Burkina Faso.

Hyman, E., Lawrence, E. and Singh, J. 1995. *The ATI/USAID Market Gardeners Project in Senegal*. Washington, D.C.: Appropriate Technology International.

Niambélé, Yacouba and Oumar Togola. 1996. *Rapport d'évaluation de l'utilisation de la pompe Ciwara par les maraîchers*. Bamako: ATI/Mali.

Norman, W. Ray. 1992. *A Field Manual for Water Lifting and Management in Small-Scale Irrigation Systems in Niger*. Niamey, Niger/Morrilton, Arkansas: Government of Niger and Winrock International.

Perry, E. 1996. *Private Irrigation in Burkina Faso and the Potential for Improved Manual Technology*. Washington, D.C.: Appropriate Technology International.

Perry, E. 1997. *Strengthening the Enabling Environment for Small Enterprise Development through Improved Technology*. Washington D.C.: Appropriate Technology International.

Promotion of low-cost and water saving technologies for small-scale irrigation

DEFINING TRANSFER OF TECHNOLOGY

Is "technology transfer" a misnomer? If it implies trying to find situations to which existing technology can be fit, then "technology transfer" would appear to be contrary to the development principle of incrementally improving what people already know. The approach should be to participatively assess farmers' requirements and then seek technology which, with minor adaptation, could suit those requirements.

In South Africa, knowledge about appropriate applications of technology for small-scale irrigation should be transferred, firstly to designers and manufacturers and then to donors and consultants. The realization that small-scale irrigation has its own unique requirements and is not merely a scaling down of well-known commercial technology, usually comes with sympathetic exposure to the actual field situation. A general problem with simple low-cost technology is that since it essentially aims to limit expenditure, it is not worthwhile for consultants' to promote it.

It must be recognized that there is a difference between transferring technology to farmers who are familiar with irrigation or even arable farming, and those who have never had experience. South Africa is an arid country with limited water resources and relatively little traditional irrigation. In addition the emphasis there has been on the creation of large and medium-scale irrigation schemes. Furthermore, there has been inadequate support to informal irrigation. There is a dire need for direct interaction between knowledgeable technical people and small-scale irrigation farmers, to create opportunities for improvement of established practices. In this regard, South Africa is eager to learn form other Southern and Eastern African countries with stronger irrigation traditions. The role of government, donor organizations and NGOs needs to be debated and decided.

Successful transfer of technology is dependent on at least three factors: the availability of the physical technology or equipment; the skills to use the equipment; and the organizational ability and know-how to manage the operation and maintenance (Still Well, 1994).

SMALL-SCALE IRRIGATION

In South Africa, the most successful small-scale irrigation farms are those which developed from farmers' initiatives. This is in contrast to government initiated, large-scale smallholder schemes, which have been rife with problems. The spirit of "small-scale" irrigation is in the fact that it is managed and controlled by farmers who are the users. Small-scale irrigation is

Marna de Lange
MBB Consulting Engineers, South Africa

easiest where a farmer has independent access to a water source. It becomes increasingly difficult as the flexibility and independence of farmers' decision-making decreases. This flexibility and independence, in turn, can be related to the number of participants on a scheme, the management requirements of the water supply infrastructure (in-scheme) and the nature of the irrigation technology (in-field).

Another important distinction is the level of risk with which the farmer prefers to operate. Intensive, highly commercial farming is high risk. In contrast, small-scale farmers often seek to reduce risk. Consequently, optimal production is often (but not always) at lower input and yield levels than those recommended for high risk farming (De Lange *et al.*, 1995). The important implications this scenario has for the choice of technology and system capacity will be discussed later in this paper.

Approximately 40 000 small-scale farmers, 15 000 medium-to-large-scale farmers, 120 000 permanent workers and an unknown number of seasonal workers are involved in irrigation farming, which consumes approximately 51% of South Africa's water on some 1.3 million ha. It contributes 25 to 30% of South Africa's agricultural output. There appears to be 202 small-scale farmer irrigation schemes involving some 47 500 ha. Only 37% of participants are commercially oriented. The remaining 63% are foodplot holders who may sometimes sell some produce (Backeberg *et al.*, 1996). This percentage does not, however, include independent small-scale farmers who are not accommodated on formal schemes.

TABLE 1
Small-scale farmer irrigation schemes in South Africa, 1996 (from Backeberg *et al.*, 1996)

Province	No. of schemes	Area irrigated	No. of farmers	No. of food plots	No. of commercial	Main commodities
Eastern Cape	25	9 460	7 365	3 752	2 613	Maize, vegetables, citrus, lucerne
Western/ Northern Cape	5	487	1 004	905	99	Vegetables, deciduous fruits, lucerne
North-West	20	3 874	880	342	538	Wheat, cotton, vegetables, maize, lucerne, fruit
Northern	102*	19 895	7 425	310	7 115	maize, vegetables, groundnuts, wheat, cotton, citrus, fruit
KwaZulu-Natal	33	8 341	18 745**	17 190	1 555	Sugarcane, maize, vegetables
Mpumalanga	17	5 429	1 689	740	949	Sugarcane, vegetables, fruit
TOTAL	202	47 486	37 108	23 239	12 869	

* Includes 22 schemes (5 257 hectares) not yet settled
** Details of farmers on 14 schemes not available

IMPROVED, LOW-COST AND WATER SAVING TECHNOLOGY

Technology is taken to mean the physical water supply infrastructure, which is a component of the scheme infrastructure and the in-field irrigation equipment, its design, construction, operation and maintenance.

When assessing the cost and water saving characteristics of technology, a distinction must be made between water supply and irrigation technology. This distinction is necessary since the funding and management of scheme infrastructure is usually a government/donors concern, while the in-field equipment is more likely to be funded and managed by farmers

themselves. In addition to the cost and the water saving characteristics of both water supply and irrigation technologies, the importance of their manageability has already been highlighted.

In South Africa, the cost of irrigation equipment is significantly limiting small farmer development. The cost of a single hosepipe is often unaffordable for beginner farmers. Therefore, a modular approach to the development of both the water supply and irrigation systems is recommended. To assess the technological requirements, we need to ask ourselves: whose priority is it to save water? With the current review of water law and water supply priorities, South Africa has a renewed national drive towards water conservation. In practice, however, farmers will use water sparingly mainly when it becomes scarce, or if time and labour consuming irrigation practices constrain water application, or if water availability limits the expansion of a highly lucrative business.

The manageability of technology can contribute to an "enabling environment" for farmer adoption. It is often argued that if water is available and easy to apply, then farmers will use more than is necessary. Therefore, to promote farmer adoption, technology should be effective, easy to apply, in the desired amount, easy to operate and maintain with local resources and affordable.

A brief discussion is presented below of irrigation technology currently being used for small-scale irrigation in South Africa (De Lange *et al.*, 1995).

Sprinkler systems

A major advantage of ***sprinkler systems*** is that a farmer can start small and expand as he learns how to use and can afford the system. If the farmer plans to expand, provision should be made at the planning stage. However, sprinkler irrigation is not always the best method for all small farmer situations. Ready access to equipment dealers and technical support are vital to achieve sustained efficiency.

Design requirements may differ from the conventional if irrigation management is to fit into the life pattern of a part-time farmer and may result in a more expensive system. For instance, shorter or varied sprinkler stand times may have to be used.

Centre pivots

Although "small-scale" is difficult to define and certainly not related to farm size only, farmers in this category generally irrigate 10 ha or less. ***Centre pivots*** are designed to irrigate relatively large areas, with circles generally ranging in size from 30 up to 100 ha in area. The equipment cost per hectare becomes very high for smaller pivots, therefore, small farmers using centre pivots have to share the equipment, which invariably leads to management and operational problems. In addition, centre pivots are mechanically complex and require skilled maintenance and are therefore not recommended for small farmer schemes.

Micro and drip (trickle irrigation)

With ***micro and drip (trickle) irrigation***, it is more difficult to detect problems than with sprinkler irrigation. This is because the emitters are so small and so many and each applies water to such a small area. If the system is not carefully monitored, application rate may

double or halve without the farmer noticing. This need for monitoring places a high demand on the farmer's time. If the farmer thoroughly understands his system and the principles of irrigation and can afford the time, then monitoring becomes an additional chore which is manageable.

An interesting aspect of micro and drip irrigation in the field, is the unexpected willingness of small farmers to actually move dripper lines between irrigations, as though they were conventional sprinkler laterals. Another example is of micro sprayers on long spaghetti tubing, initially installed to irrigate fruit trees, but which are now also being moved around like a miniature replica of a dragline system for intercropping vegetables between the fruit trees .

The possibility of such laborious irrigation practices has hitherto been discounted on larger farms, where they are impractical. However, this is a good example of how, under special circumstances, practices which seem unacceptable or ineffective can, in fact, make a significant contribution to both management and production.

Micro irrigation, which has only been used to a limited extent by small farmers therefore warrants further investigation. Unless the vulnerability of the system can be reduced, its applicability remains limited for farmers with inadequate access to technical support, training services and equipment dealers. This will be the subject of a WRC study commencing in 1996.

Flood irrigation

Flood irrigation is not suitable for all soil conditions, but has a major advantage over other types of irrigation for small farmer irrigation (or any situation where access to support services is limited). The advantage of the system is that it usually can be designed to operate at very low running costs with gravity feed, without pumping or any mechanical equipment. While the maintenance of infrastructure like weirs, canals and diversion structures is important, this can be handled in a regular, programmed and largely preventative manner. Emergency breakdowns requiring urgent access to support services are rare in gravity systems.

Flood irrigation is regarded as more ***labour-intensive*** than mechanized systems. However, it is often more suitable where small farmers live a considerable distance from their fields and can travel to the fields only once, complete the irrigation in three to four hours, and then return home. In comparison, a farmer-housewife may find it impractical to travel to the fields a number of times per day to shift sprinkler lines.

Short-furrow or furrow-basin flood irrigation

This system has the additional advantage that weeding and insect control are done simultaneously with the irrigation. Another advantage of furrow-basin irrigation is that there is very uniform distribution of water across the whole field, even in cases where the gradient varies or where the flow rate is inconsistent. Variations in gradient or flow rate would make other methods of flood irrigation difficult or even impossible.

Small-scale technology needs in South Africa include the following:

- affordable, reliable, robust, low volume pumps with sufficient pressure to run one or two sprinklers at a time;
- general improvement of the ability to design and develop appropriate short-furrow flood irrigation systems; and
- general sensitization of designers toward small-scale requirements.

FACTORS HAMPERING TRANSFER OF APPROPRIATE SMALL-SCALE IRRIGATION TECHNOLOGY

The use of appropriate technology on small-scale irrigation developments could be improved significantly. Some of the problems most frequently encountered are discussed below.

Lack of interaction between farmers and technical advisers

Farmers are still not sufficiently part of the process of choosing the technology suited to their circumstances, especially when schemes are being developed or rehabilitated. The interaction between technical advisors and farmers seems to be particularly difficult when:

- technical advisers lack the skills, commitment and/or back-up to interact meaningfully with the farmers; and
- farmers have no irrigation experience or have had inadequate exposure to technologies to debate the options.

Water saving

Saving water is often not a farmer priority.

Cost of development

The cost of irrigation development is prohibitive, especially for schemes.

Consultants' costs

Consultants' costs possibly could be reduced if the scope of pre-feasibility reports include only relevant information to back up recommendations and more reference to examples and precedents. Such a report could be generated through communities' own participative analysis and planning. These studies, as well as standardized design functions, could be handled by well-trained, local "technical irrigation assistants" instead of consultants.

System capacities

The estimation of scheme and in-field system capacities is often unrealistic. In most cases the conventional approach is recommended and is then applied without modification. CROPWAT is regarded as being the desired procedure for estimating crop water requirements. The crop factors utilized assume, by definition, "a disease free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the

given growing environment". This is a situation rarely applicable in the case of cash-strapped risk-avoiding small farmers. This is recognized by low yield estimates and cash returns but not by appropriately adjusted irrigation requirement determinations.

It is common practice to design system capacity to keep up with atmospheric demand in the peak month. Few planners utilize the valuable scheduling module in CROPWAT which quantifies the buffer effect of water stored in the profile and periods of under-irrigation and stress at peak. Usually it is found that when the realities of production conditions are taken into consideration system capacity can be reduced to half or less without irrigation becoming the limiting factor in production. There is, however, another side to the coin. Irrigation hours are often grossly over-estimated, assuming night irrigation and the continuous availability of labour, and this can lead to inadequate system capacity.

It can be argued that there should be sufficient capacity to cater for indifferent weed control and shallow soils, but this is a fallacy. There is no way in which effective irrigation technologies can be found, developed or applied in circumstances where the natural resources and the basic crop production know-how are lacking.

Reduced capacity may limit expansion possibilities, but some innovation could possibly help avoid this by using a modular approach to water supply and irrigation design.

Type of technology

The type of technology often does not lend itself to modularity and may also limit the possibilities for local manufacturing and/or trading.

Design experience

There is inadequate design experience for development of irrigation schemes for management by the users. In some cases the in-field irrigation system limits farmers' flexibility and decision-making. Operation and maintenance often receives inadequate attention and is often the responsibility of government agencies.

Availability of suitable technology

The available technology is not always suited to small-scale irrigation requirements. For example, small pumps with sufficient flow rate and pressure from which one or two sprinklers can be run, are not available in South Africa. Currently, fire fighter pumps are being used, but they have not been designed for the long operating hours typically needed for irrigation purposes.

Demand and supply of equipment

Manufacturing of equipment specifically suited to small-scale circumstances is probably hampered by the (lack of) demand. A thorough market analysis on the quantities needed on a regional (SADC) basis could provide opportunities for an integrated approach.

PROMOTING IMPROVED SMALL-SCALE IRRIGATION

Start with the people

In South Africa, we have not had sufficient success with small-scale irrigation to be able to standardize or generalize. In that respect, we are very much in a developing phase and have

to treat each project as being unique and specific in its requirements. One successful development (albeit non-irrigation) provides us with some pointers for a possible approach, namely the Phokoane maize project. Much of the success of this people-based development is attributed to Johann Adendorff's needs analysis approach. It provided him with the basis for the interventions and farmer training that brought about a tenfold improvement in average production on an 8 000 ha area consisting of individual plots of between 1-2 ha each.

Once a needs analysis has been done and the technical aspects of production and the appropriate training established, the design or selection of appropriate equipment can be undertaken.

It appears to be important to start where success is most likely. There has been much debate about what this means in practice, but based on observation, the farmers' will to succeed appears to be paramount. Further, success is generally easier where tradition and experience is available to build on. Marketing outlets for produce are essential for sustainable production, while success is possible despite less than ideal natural resources.

Sharing experience

"Regular personal interaction between those who can and those who want to" (Crosby, 1996) has proved to be a powerful tool for improvement at all levels. Field visits and workshops could possibly be enhanced by mobile demonstrations which may have wider impact and which could focus discussions amongst and between farmers, technical people and possibly even donors.

Improve accessibility

It would sound commonplace to say that adequate access to equipment, design and installation capacity, spares/maintenance support, training, finance and enabling government policies would help promote improved small-scale irrigation. Assuming that the criteria of adequacy, appropriateness and affordability apply throughout, the following ideas are presented for consideration.

Access to equipment

The idea of travelling or round robin salesmen to improve accessibility to equipment and spares, has been mooted. The idea looks particularly promising where sales visits could coincide with weekly village market days and providing that prices could be kept reasonable. Adequate technical training of salesmen would enhance their contribution significantly.

Access to design and installation

The role that well-trained, motivated local technical irrigation assistants could play, has been discussed tentatively.

Access to spares/maintenance support

Local businesses providing technical irrigation support should be encouraged. While local (village level) manufacture may not always be viable in South Africa, local trading and spares supplies could probably be incorporated into *spaza* (informal) type trading.

Access to training

All disciplines involved in small-scale irrigation development could benefit from appropriate training or briefing. Farmers have expressed a need for hands-on familiarization with technology and generally seem to lack a basic understanding of irrigation principles. All the other disciplines (e.g. designers, support personnel, donors) in turn, need at least briefing on the nature and idiosyncrasies of small-scale irrigation.

Access to finance

Funders' ability to support small-scale, low-cost, community/farmer initiated projects have been inadequate in South Africa. Funding criteria should be very clear and well-known to applicants and should possibly place more emphasis on the importance of communities' own analyses, planning and responsibilities and less on external control measures. Pre-feasibility requirements should be on a need-to-know basis to avoid the costs involved in elaborate studies and should be structured to facilitate quick decision-making and feedback to applicants.

Supporting government policies

The overall understanding of the requirements of sustainable small-scale irrigation development and active support to small-scale farmers could be improved significantly by increasing contact between farmers and knowledgeable technical support staff in the field.

Unfair competition through bulk supply by outside agents should be avoided, especially if spares are likely to be problematic. Instead, local manufacture or trading should be promoted where possible, through local service providers rather than government or agency monopolies.

Technologies for water harvesting and soil moisture conservation in small watersheds for small-scale irrigation

Water is essential for all life and is used in many different ways - for food production, drinking and domestic uses and industrial use. It is also part of the larger ecosystem on which bio diversity depends. Precipitation, converted to soil and groundwater and thus accessible to vegetation and people, is the dominant pre-condition for biomass production and social development in drylands. The amount of available water is equivalent to the water moving through the landscape. It also fluctuates between the wet and dry periods. Fresh water scarcity is not limited to the arid climatic regions only. Even in areas with good supply, the access to safe water is becoming a critical problem. Lack of water is caused by low water storage capacity, low infiltration capacity, large inter-annual and annual fluctuations of precipitation and high evaporative demand.

Irrigation in Africa is a privilege since, the cost of providing irrigation to one hectare could be as high as US$ 20 000/ha and therefore cannot be implemented. Even for small-scale irrigation using groundwater, well (both open and tube well) construction is costly. It may amount to more than US$ 10 000 to provide irrigation water for one hectare of land.

Irrigation potential which exists in South and East African countries is much more than the presently irrigated area. The geographical area, irrigated area at present and irrigation potential for selected countries are given in Table 1. The table indicates the possibilities of bringing a larger area under irrigation in these countries for food security.

A variety of essential soil moisture and water conservation technologies must be adopted to reduce the cost of irrigation, extend it throughout and promote sustainable small-scale irrigation on a watershed basis. These technologies are essential especially in drought-prone areas. Even though drought is a purely natural calamity caused by the failure of (monsoon) rain, it can be minimized by careful planning and operation. During good rainy years, excess rainwater should be stored in the soil and also underground using suitable soil moisture conservation measures and water harvesting structures on a watershed basis. This stored water can subsequently be used for irrigation.

CONCEPTUAL APPROACH

Watershed development and management implies an integration of technologies within the natural boundary of a drainage area for optimum development of land, water and plant resources, to meet the people's basic needs in a sustained manner. A watershed is an area from which runoff resulting from precipitation flows past a single point into a large stream, river, lake or pond. Each watershed is an independent hydrological unit. It has become an acceptable unit of planning for optimum use and conservation of soil and water resources.

R.K. Sivanappan
Saivy Pumps Ltd., Coimbatore, India

TABLE 1
Area, population, irrigation details of selected countrias

Details	Malawi	Tanzania	Zambia	Zimbabwa	Mozambique
Area (M ha)	11.85	94.50	75.26	39.08	80.18
Population (Million)	10.08	28.85	9.20	11.00	15.50
Rainfall (mm)	1014	937	1011	652	969
Cultivable area (M ha)	3.6	40	16.35	--	36.0
Cultivated area (M ha)	2.1	6.3	1.03	2.80	3.6
Irrigation Potential (M ha)	0.162	0.83	1.40	0.55	3.30
Irrigated area (M ha)	0.09	0.15	0.15	0.14	0.11
Population per sq km	92	31	12	28	19

The concept of integrated watershed development refers to the development and management of the resources in the watershed to achieve higher sustainable production without deterioration in the resource base and any ecological imbalances. This concept requires the formulation and implementation of a package of programmes with activities for optimum resource use in the watershed without adversely affecting the soil and water base or life supporting system. The concept assumes more importance in the context of planning for sustained development. Watershed development aims at preventing watershed degradation resulting from the interaction of physiographic features. It eliminates unscientific land use, inappropriate cropping patterns and soil erosion, thereby improving and sustaining productivity of resources leading to higher income and living standards for the inhabitants in the watershed area. It therefore involves restoration of the ecosystem, protecting and utilizing the locally available resources within a watershed to achieve sustainable development.

Rainfall failure occurs once every 3 to 5 years and is usually below 50% of the average annual rainfall of the region. During periods of rainfall failure, the groundwater level lowers since fluctuations in the water table levels depend on the rainfall when both surface and groundwater availability becomes critical. Drought begins to prevail and there is difficulty to cope up with the water demand during this period. Similarly, in some locations or areas water shortage is observed just before the rainy season commences. These two situations can be managed if suitable soil and moisture conservation measures are systematically implemented on a small watershed basis.

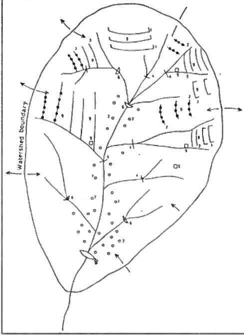
There are always strong links between soil conservation and water conservation measures. Many actions are directed primarily to one or the other, but most contain an element of both. Reduction of surface runoff can be achieved by constructing suitable structures or by changes in land management. Further, this reduction of surface runoff will increase infiltration and help in water conservation.

APPROPRIATE STRUCTURES AND THEIR FUNCTIONS

To increase the period of water availability and overcome water scarcity in drought years, the following activities can be implemented in the field for a compact, viable watershed of about 200 - 500 ha.

Soil and water conservation can be approached through agronomic and engineering procedures. Agronomic measures include contour farming, off season tillage, deep tillage,

FIGURE 1
Soil and water conservation measures on a watershed basis



LEGEND

1. Contour trenching
2. Contour stone wall
3. Contour bunds
4. Check dams or gully plugging
5. Farm ponds
6. Percolation ponds
7. Wells
8. Irrigation tanks
9. In situ moisture conservation measures

mulching and providing vegetative barriers on the contour. These measures mainly prevent soil erosion but will also help in improving soil moisture availability in the watershed.

The engineering measures adopted differ with location, slope of the land, soil type, amount and intensity of rainfall. Depending on these parameters, the methods commonly used are contour trenching, contour stone walls, construction of temporary and permanent check dams and gully plugging structures. Additionally, percolation ponds, silt detention tanks and irrigation tanks are constructed to harvest water and recharge it to the groundwater for use in agriculture (irrigation). Farm ponds can also be constructed for every 4-5 ha in the watershed to provide protective/supplemental irrigation.

The above soil and water conservation management and water harvesting programme should be implemented in an integrated manner on a catchment/watershed basis (Figure 1).

Functions of the structures

Contour bunds, contour barriers (vegetative and stone), contour trenches and contour stone walls will not only prevent soil erosion but also obstruct the flow of runoff water.

Consequently, the obstructed water will increase the soil moisture and recharge the groundwater in the area.

Check dams: This may be a temporary structure constructed with locally available materials. The various types are: Brush wood dam, loose rock dam and woven wire dam. The main function of the check dam is to impede the soil and water removed from the watershed. This structure is cheap, but lasts about 2-5 years. The cost of the structure is about US$ 200 - 400 depending on the materials used, the size of the gully and the height of the obstruction (dam). A permanent check dam can be constructed using stones, bricks and cement. Small earth work is also needed on both sides. Costs vary from US$ 1 000 - 3 000 depending upon the length and height of the dam. A little water is also stored above the dam. This water recharges the groundwater.

Percolation Pond: The percolation pond is a multipurpose conservation structure depending on its location and size. It stores water for livestock and recharges the groundwater. It is constructed by excavating a depression, forming a small reservoir or by constructing an embankment in a natural ravine or gully to form an impounded type of reservoir. The cost of this type of structure is estimated at around US$ 5 000 - 10 000. The capacity of these ponds or tanks varies from 0.3 to 0.5 mcft (10 000 - 15 000 m^3). Normally 2 or 3 fillings are expected in a year (season) and hence the amount of water available in one year in such a tank is about 1 mcft to 1.5 mcft (30 000 - 45 000 m^3). The cost for one mcft (30 000 m^3) varies from US$5 000 to 15 000. This quantity of water, if it is used for irrigation, is sufficient to irrigate 4-6 hectares of irrigated dry crops (maize, cotton, pulse, etc.) and 2-3 hectares of paddy crop.

Irrigation Tank: The main function of this storage structure is irrigating crops. It is constructed below the above-mentioned structures in a watershed. In Tamil Nadu, India, each tank irrigates from 10 to 5 000 hectares. In south India, there are about 2 000 000 tanks, irrigating about 3.5 million hectares. Earthen bunds are reinforced with masonry to collect and store rainwater for irrigation. The cost of this tank (dam) depends upon the size, location and site condition. It costs about US$ 1 500 - 2 500 to irrigate 1 ha of land. Water from the tanks is normally used to grow paddy crop.

Apart from the above, to increase moisture availability to agricultural and tree crops, in situ moisture conservation techniques must be adopted in addition to the large scale soil and moisture conservation and water harvesting structures in the watershed.

The following are some of the *in situ* moisture conservation measures which can be practised in the watershed to increase production.

For agricultural crops, the measures adopted are forming ridges and furrows, broad bed and furrows, basins, tie ridging (random tie ridges) and water spreading.

For tree crops micro catchment, saucer basin, semi-circular bund, crescent shaped bunds, V ditch technology, catch pits and deep pitting can be practised.

In addition to the above measures and structures, small storage structures with a water storage capacity for an area of about 0.4 to 0.5 ha can be constructed in large numbers one for every 10 to 20 ha catchment or watershed at the foot hills slopes and hilly areas. These storage facilities would attenuate the floods during storms. These measures will also ensure

soil moisture for good growth of trees grown down stream recharging the groundwater in the region and making available more water for drinking and irrigation water.

CONSTRUCTION PROCEDURES

The procedure for the construction of tanks and check dams, on a watershed basis, is as follows. Detailed studies are first made of the watershed to determine its current erosion condition, land use and water balance condition. Based on these data, decisions are made on the construction of check dams (temporary/permanent), percolation tanks and irrigation tanks (refer to Figure 1). The community in the watershed should be involved in planning and selecting the type of structures and locations of the structures. If a large quantity of water is lost through runoff from the watershed, 2-3 percolation tanks or one irrigation tank can be planned based on water availability. A number of check dams can be provided to arrest erosion and to plug the gullies in the rivulets at appropriate places.

The construction can be done using human labour if necessary or by a mix of mechanical and human effort. In India, these works are mostly executed by labourers to give employment to the village people. Only 10% of the work is done mechanically (bulldozer) i.e., digging the foundation and excavating earth to form bunds. Otherwise 80-90% of the work can be done by machines, if employment is not a criterion.

The cost of construction of the above-mentioned structures depends upon the soil type, the size of the tank and season of construction. The proportions of earth and masonry works for the three different structures are as follows.

Type of structures	Earthwork (%)	Masonry and concrete
Check dam	10	90
Percolation tanks and irrigation tanks	40-70	30-60

The average costs of construction of percolation ponds are as follows: (actuals taken from the estimates)

Type of construction	Labour	Capacity of the tank (mcft)	Earthwork cost in US$	Material cost in US$	Cost/Unit (1 mcft or 30 000 m^3)
Percolation pond 1	90 %	0.43	4 000	300	10 000
Percolation pond 2	93 %	0.43	4 200	300	10 000
Percolation pond 3	70 %	0.30	2 000	4 500	25 000
Percolation pond 4	77 %	0.25	2 000	5 000	28 000
Percolation pond 5	75 %	0.25	2 000	3 000	25 000

The actual construction is undertaken when the community is free from agricultural work and the works are spaced in such a manner that the construction will be completed before the rain (monsoon) commences, so that the structure will be used immediately. Small structures are completed within 2-3 months while a large one takes about 7 - 9 months.

These tanks or dams are constructed by Government without the involvement of people during construction. The maintenance is normally not done but is the responsibility of the Government. If the people are involved in constructing the structure they feel ownership and

will take responsibility for maintenance. Since the work is given to the contractors the quality of the construction is also questionable. Wherever the community is involved in the construction, they undertake the maintenance of the structure themselves.

Users' (farmers') participation

The efficiency of a tank or pond depends on the organization of its beneficiaries. This organization of beneficiaries are required for each and every tank, especially for maintenance and rehabilitation. The role of the water users' association (WUA) or farmers' organization (FO) in general is as follows.

- Planning including selection of site.
- Construction.
- Distribution of water in irrigation tanks.
- Maintenance of the structures.
- Mobilization of resources for the work, management and maintenance.
- Involving themselves in the work.
- Resolution of the conflicts.

Linkages should be established between the farmers and various organizations. The NGOs are required as a catalyst and to create awareness among the farmers about efficient utilization of the resources.

It is said that users' participation is necessary for better utilization and management of the resources. In practice this participation is very difficult to achieve. To some extent farmers' participation in the management and utilization of irrigation tanks is forthcoming. However, involving farmers is not such an easy task with check dams and percolation ponds, since there is no direct benefit to the farmers as in the case of irrigation tank.

Involvement of farmers in system management and project management from planning to operation and management of the system should be stressed. Coordination among the association members has to be intensified for proper guidance.

PLANNING CONCEPT, DESIGN AND CONSTRUCTION OF THESE STRUCTURES

When selecting the construction site of check dams, percolation ponds and tanks, the following criteria can be considered.

Check dams: This is constructed across rivulets and gullies to control erosion, prevent gully formation and to arrest the flow of water to allow it to go underground. A number of such obstructions will be useful for soil and moisture conservation measures. Inexpensive, temporary structures can be constructed using vegetation, stone or brushwood, available at the site. Large numbers can be provided to reduce erosion and formation of gullies. Permanent check dams can be located at the junction of one or two streams or gullies using masonry structures.

Percolation ponds: The following factors may be considered :

- It should not be located in heavy soils or soils with impervious strata, otherwise the top soil should be porous.
- Suitable and adequate soil should be available for forming embankments.
- The ideal location of the pond will be on a narrow stream with high ground on either side of the stream.
- Simple, economic and efficient surplus arrangement should be possible.

Pond size should be decided on the basis of the catchment area and the number of fillings possible for the pond in the area.

Irrigation tanks: The location should be such that it should receive water from a large catchment area.

- There should be land below the site suitable for irrigation.
- Cooperation and coordination of the farmers and the community is essential to use the water.
- The location should be such that it will be a narrow point with high ground and wide open space in front of the tank location so that a large quantity can be stored with minimum cost.

A model design of a percolation pond/tank and check dam is given in Appendix 1.

After the plan and estimates are prepared and approved by the appropriate authority, construction can be entrusted to village people (beneficiaries) in case of check dams or percolation tanks and to the WUA and/or FO in case of irrigation tanks. Not much operation and management is needed in the case of check dams and percolation tanks but irrigation tanks must be visited regularly to release water and conduct repairs and maintenance. The WUA or FO can be involved from the time of construction, operation of the system and maintenance of the structure.

Performance Assessment and Lessons Learned

Farmers should always be involved in planning and executing field programmes. Management and new techniques should not become a continuous burden to the farmers. The design and implementation of a conservation and rehabilitation programme is likely to be most successful, if they are the product of interdisciplinary work between technical staff and those experienced in economic and social issues.

Based on the above background, the author had an opportunity to study many projects implemented by NGOs, government departments and farmers on water harvesting and soil moisture conservation in small watersheds in India. After visiting all the projects and following discussions with the people concerned, the following assessments were made about their projects and the lessons learned from the experiences.

In one village, owing to the inspiration of a dedicated NGO, the village has dramatically improved after the villagers executed all the development work including soil conservation and water harvesting works. Though the annual rainfall was only 450 - 500 mm, the groundwater table was maintained at a depth of 6 -7 m and there is no water scarcity even

during drought years in that village. The farmers are using drip irrigation for widely spaced fruit and orchard crops and are planting trees in barren and common lands.

In another large project (40 000 ha) funded by the World Bank, soil and water conservation and water harvesting measures were conducted on a watershed basis. Though it was a Government project it was implemented with the help and involvement of the community from the planning stage to execution. Consequently the project achieved its goal. The farmers obtained 150 - 200% more yield. The groundwater table in the watershed was raised and the community had no difficulty to get water. At the same time, another project failed and expected results were not been achieved because farmers were not involved. Therefore it is clear that water availability can be increased if soil conservation and water harvesting measures are implemented on a watershed basis involving the community. In addition more water will be available for small-scale irrigation, which will assist in improving the people's living conditions and food security in the coming years.

APPENDIX 1

EXAMPLES OF DESIGN OF CHECK DAM, PERCOLATION PONDS AND TANKS

The design procedure for the check dam (permanent), percolation tank and irrigation tank is more or less the same.

In all three cases, the weir length (surplus weir) has to be designed and/or calculated.

In the case of percolation tanks and irrigation tanks, the capacity of the tank has to be calculated on the basis of the rainfall and catchment area of the tank. For check dam, this is not necessary.

The method of calculating the weir length and the capacity are the same in all cases.
The procedure is as follows:

- select the site for the tank or check dam.
- from the Topo sheet or village map, find out the correct catchment area of the watershed at that location.
- take the cross sections and longitudinal section of the stream or gully where the tank or dam is constructed.
- based on the levels taken, prepare 50 cm contour for sufficient area to decide the water spread area and the capacity of the tank based on the yield of the watershed.

Example:

Catchment area	- 40 ha
Monsoon /Rainfall season	- 625 mm
Yield from catchment assuming the catchment is good. (more yield) tables are available.	- 51 480 m^3
Capacity may be designed as 1/3 of the yield from the catchment i.e.	- 17 000 m^3

Deciding full tank level (FTL), Maximum water level (MWL) and tank bund level (TBL):

From the levels taken, draw the contour lines at every 50 cm interval between the bed level and the highest ground level at the site. From these contour lines, the capacity of the tank at 0.5 m, 1.0 m, 1.5 m and 2.0 m. height above the bed level is calculated. The contour (level) at which the tank can store 1/3 of 51 400 m^3 i.e. 17 000 m^3 is the required height of the weir. That is called full tank level (FTL). For small tanks, the height of flow over weir is taken between 0.30 - 0.60 m and this level is known as maximum water level (MWL). The tank bund level (TBL) is calculated by adding 1m or more based on the height of the water stored above the bed level of the tank.

Design of weir:

Maximum Discharge $Q = CIA/360$

Where Q = Discharge in cumec

I = Intensity of rainfall (25 mm/hour)

A = Area of catchment in ha.

To decide the length of the weir

$$Q = CLH^{3/2}$$
$$= 1.67\ LH^{3/2} \text{ (broad crested weir } C = 1.67)$$
$$L = Q/CLH^{3/2} = CIA/360CLH^{3/2}$$

Where C = Constant = 1.67

L = Length of the weir

H = Flow height over weir

After deciding the length of the weir (L), other structural calculations may be made, including the body wall, wing walls and apron. Finally the stability of the structure is checked.

Review of the irrigation equipment manufacture and supply sector in India

India's economy is based mainly on agriculture and it is the backbone of the country. India's agriculture depends upon the timely monsoon and the amount of rainfall in any year. To avoid the uncertainty and vagaries of the monsoon, farmers in India resort to various methods of irrigation. India, being a vast country with much variation in geographical conditions, needs several irrigation techniques.

In areas of shallow water levels (1-6 metres head) axial flow or mixed flow pumps are used to lift water. Where water levels are at 6-40 metres head or on river sides, mostly radial flow pumps are used.

For deep bore wells submersible or jet or compressor pumps are used depending on head and discharge requirements and on availability of water in the bore well (yield).

PUMP INDUSTRY IN INDIA

The first electric motor in India was manufactured in Coimbatore in 1930 and thereafter the motor pump industry expanded rapidly there. Today 60% of India's requirements of domestic and agricultural pumpsets are made in Coimbatore. The Southern India Engineering Manufacturers' Association (SIEMA) (established in 1952) has 215 members, most of whom manufacture motors and pumps of various types. Indian pumps are made according to the specifications of the Bureau of Indian Standards (BIS). Coimbatore (with 1.2 million population) is also famous for Textile machinery manufacture and is rated sixth in the World. It is called the "Manchester" of South India due to the presence of hundreds of spinning mills, cloth and garment manufacturing units in and around Coimbatore. Besides Coimbatore, Ahmedabad, Baroda, Calcutta and Dewas are the other places where agricultural pump industries are situated. Similarly Rajkot, Agra and Kolhapur are famous for oil engines and Rajkot alone accounts for 50 percent of engine production.

SPECIAL CRITERIA FOR MOTOR AND PUMP DESIGN

Apart from the general requirements for motor and pump design such as rating, power factor, head, discharge and efficiency, the following factors are to be considered during design of pumpsets.

C.R.S. Sundaram
Secretary, Southern India Engineering Manufacturing Association
Coimbatore, India

TABLE 1
Production particulars

Product type	Quantity per year	Value
Single phase monoblock pumpsets 0.5 HP to 2 HP range	2 million sets	
Three phase monoblock pumpsets 2 HP to 30 HP range	600 000 sets	$ 500 million
Submersible pumpsets 3 HP to 30 HP range	600 000 sets	
Diesel engines up to 10 HP	200 000 engines	
above 10 HP	12 000 engines	

1) In India, the three phase electricity power supply to villages varies from 240 - 450 volts with a 47.5 to 51 cycle frequency (standard 415 volt and 50 cycle frequency). Average power supply is 6 to 8 hours daily during summer and most of the time, power supply is around 240 - 300 volts. In the single phase, voltage varies from 140 - 250 volts.

2) During summer the ambient temperature is 35^{o} to 40 ^{O}C with dry humidity, when heat dissipation by motors or engines is poor. Hence pumpsets are designed for such extreme conditions.

3) The literacy level in Indian villages is very low as is the economy. Consequently, people cannot afford to spend on the maintenance of equipment.

Hence, motors, pumps and engines are designed for easy installation, trouble free operation, and easy maintenance for a long service period.

Small Industries Testing and Research Centre (SITARC)

This Centre was set up in 1986 for testing motors, pumps, monoblocks, submersible pumps, raw materials and for calibration of instruments. SIEMA contributed an 8 000 m^2 piece of land to SITARC where the testing centre is now functioning. The present cost of the land is approximately US$ 500 000.

SITARC has the following divisions and facilities:

Mechanical, electrical, materials testing and meteorology divisions
Research and development, design and engineering divisions
HRD/consultancy/information cell
Prototyping products and tools in model tool room

SITARC is approved as a research centre by the Ministry of Science and Technology, Government of India. It is accredited by NABL in the disciplines of mechanical, electrical, chemical and fluid flow and recognized by the Bureau of Indian Standards for ISI testing. Test certificates are recognized by the Export Inspection Agency, RITES, Ministry of Defence, State Electricity Board and the State Water and Drainage Board.

SITARC Pump Institute funded by UNDP, UNIDO, Government of India and the Government of Tamil Nadu, is in the process of setting up the most modern pump testing institute. The cost of the project is US$ 5 million.

Product Quality and Performance

The BIS assists exporters and industry to meet international standards and quality specifications for global acceptance through its standards formulation, certification, technical and other related activities. BIS is actively involved in the International Organization for

Standardization (ISO) and International Electro-Technical Commission (IEC) and also participates in various technical committees of ISO and IEC.

Product quality begins from the selection of raw materials. The BIS has defined materials specifications for each component of pumps and motors and has specified time schedules for calibration of gauges, meters and other tools used in regular testing of pumps. All industries are required to keep calibration records of their equipment and meters.

It is mandatory that qualified and properly trained technicians and inspectors are appointed to conduct testing. Most industries have their own quality control system which are used during the manufacturing stages of each component. A few SIEMA member units are beginning to obtain ISO 9001 and ISO 9002 system certification. Medium and large scale industries use the latest model CNC machines and fully computerized testing facilities to achieve the desired quality.

BIS has issued separate standard specifications for each type of pump. Similarly, testing facilities for agricultural, jet and submersible pumps are also specified by BIS to be followed by the industries.

Each pump manufactured will undergo the following testing procedure before despatch:

Routine test for Motor:

1) No load current, watts, speed (clock wise and anti clockwise)
2) Breakaway test to find starting torque
3) Full load test of watts, amps, speed, power factor, efficiency slip and temperature
4) For single phase motor, test for moisture proof and current leakage for user safety

Routine test for Monoblock in addition to motor test:

5) Test for overall efficiency of the monoblock
6) Test for guarantee of performance at duty point
7) Overload test in operational range

Because of such a stringent quality control system, pumpsets thus manufactured will have high reliability and superior performance.

TYPES OF PUMPS, PERFORMANCE RANGE AND PRICE

1) Axial flow pumps
2) Monoblock pumps - single phase (240 Volts)
3) Jet centrifugal combination pumps
4) Monoblock pumps - three phase (415 Volts)
5) Submersible pumpsets
6) Direct coupled or belt driven centrifugal pumps

Axial flow pumps

Axial flow pumps or propeller pumps are used for a head range of 1-6 metres and give high discharge. No priming is necessary for this pump and it operates at 80-90 percent of pump efficiency.

Capacity	Head Range (m)	Output lps
5 - 30 HP	1 - 6M	60/300

Prices for Axial flow pumps vary depending on the requirements of head and discharge.

Single phase 2880 rpm centrifugal monoblocks

These pumpsets are easy to install, lightweight, ruggedly built and designed for trouble free operation. They are of monoblock construction with a common shaft for the motor and pump. High efficiency of these pumps minimizes power charges. Numerous applications include irrigation of small land holdings, gardens, domestic water supply and circulating systems. Motors are made of TEFC body and covers are of cast iron with capacitor start and run, Class "B" insulation running at 2880 RPM and enclosures with protection IP44 & IP 55. Pumps are of end suction, centrifugal design. Casings are of cast iron. Impellers are bronze and dynamically balanced. These Monoblocks are fitted with high quality mechanical seals for long reliable life.

Capacity	Head range (m)	Output LPM	Average price FOB Durban ($)
0.5 HP	6 - 20	220/70	105
1.0 HP	6 - 25	400/75	135
1.5 HP	6 - 30	440/90	165
2.0 HP	8 - 30	480/150	182

Jet centrifugal pump combination sets

These pumpsets are used in borewells and openwells where suction depth is 8 - 60 metres. They are easy to install on borewells of 75 mm (3") and larger. As there are no moving parts inside the borewell jet units, maintenance is easier than with submersible pumps. Jet units are available in many sizes for various suction lifts.

Range	Suction head range (m)	Output LPH	Average price FOB Durban ($)
0.5 HP	9/15	2000/1100	135
1.0 HP	9/30	2700/1200	175
1.5 HP	15/40	2500/1200	205
2.0 HP	15/50	2900/1100	233

Three phase monoblock pumpsets

Motors are the TEFC 1440 / 2880 RPM squirrel case induction type. Pumps are the single stage, end suction type and are fitted with cast iron impellers and casings. Stainless steel bushes and brass impeller locking nuts are provided at the pump end. Gunmetal gland, stainless steel studs and brass nuts are fitted to avoid rusting and to make it easy to replace asbestos packing ropes. Various models are available in monoblock range for selection to meet specific requirements.

Capacity	Head range (m)	Output LPM	Average price FOB Durban ($)
2.0 HP	6/20	400/220	220
3,0 HP	6/24	1 580/380	280
5.0 HP	8/30	2 000/500	330
7.5 HP	8/42	3 200/500	455
10.0 HP	8/53	3 720/480	560
12.5 HP	8/62	4 000/560	640
15.0 HP	8/72	4 000/520	695
20.0 HP	20/80	2 300/420	890
30.0 HP	30/80	2 500/900	1 260

Three phase submersible pumpsets

Submersible motors are designed to operate with 250/450 volts, 50 Hz, 3 phase AC supply. They are fitted with wet type, water-filled, water-lubricated squirrel cage induction motors. The motor casing is of stainless steel. The starter winding is made of PVC/Polyester film, wrapped around waterproof copper winding wires. The rotor laminations are fitted with electrolytic grade copper rods, and the ends are brazed with forged copper end rings, mounted on a stainless steel shaft, which is hardened and ground to ensure long life. The shaft is supported by two sets of leaded bronze journal bearings lubricated by water. The axial thrust generated by the pump is absorbed by a thrust bearing fitted at the bottom of the motor. The motor is seated on radial seal rings.

The pump is of multistage centrifugal design, with radial or mixed flow impellers which are of bronze and dynamically balanced. The diffusers are designed to give best possible efficiency and are built into the casings with replaceable guide bushes for easy maintenance. The pump shaft is made of stainless steel hardened and ground. A strainer is fitted at the inlet of pump to prevent entry of solid particles.

Single phase submersible pumpsets suitable for 100 and 115 mm borewells are also available.

Submersible pumps can be installed in bore wells and very deep wells for irrigation schemes, domestic uses and industrial requirements. Submersible pumps are versatile and are suitable for sprinkler irrigation schemes as booster pumps.

Submersible pumps suitabla for 150 mm bore diamater

Motor HP	Price FOB Durban	Radial flow pump price	Mixad flow pump prica
3.00	315	Basic 3 stage	Basic 3 stage pump
4.00	328	pump - $ 110	$ 188
5.00	350	Every additional	Every additional
6.00	390	staga cost axtra - $ 18	stage cost extra
7.50	450	can offer up to	- $ 36
10.00	510	can offar up to	can offar up to
12.00	580	20 stage	12 stages
15.00	620		

Direct coupled and belt driven centrifugal pumps

Direct coupled and belt driven centrifugal pumps are single stage, radial flow end, suction type with horizontal shaft and vertically split casings. Pumps are fitted with pulleys or with flexible couplings, to be driven by electric motors or diesel engines. Direct coupled pumps are supplied with a common base plate for fixing the drive units.

Direct coupled and belt driven centrifugal pumps

Siza in	HP reqd.	Head ranga (m)	Output LPM	Average price FOB Durban ($)
64 X 50	3.0	9/15	800/500	130
75 X 65	5.0	9/18	110/600	140
75 X 75	5.0	9/15	1 440/900	140
100 X 75	5.0	6/13	1 600/1 000	150
100 X 100	5.0	6/12	2 000/1 200	220
125 X 125	7.5	6/13	2 700/1 800	290
150 X 150	10.0	6/10	4 000/2 000	310

Diesel engine

Vertical four stroke cycle, single cylinder compression ignition "water cooled"/"air cooled" cold start diesel engine

Diesel engines are designed as prime movers for agriculture, with high efficiency, low fuel and lubricating oil consumption. Grade : 15 and Grade : 20 cast iron and EN 9 materials are used in the manufacture of these engines. Rigid inspection of components at every stage of the assembly makes every part easily interchangeable. Each engine is tested thoroughly for speed, output and fuel consumption according to the BIS specifications.

Thermo - Syphen or a fresh water system is used for water cooled engines. A blower is attached with a fly wheel for air cooled engines. Single cylinder diesel engines are manufactured up to 10 HP and for above 10 HP, multi cylinder diesel engines are manufactured according to specifications.

Single Cylinder Water Cooled Engine	**Average Price FOB Durban ($)**
5.0 HP 1 500 RPM	420
6.5 HP 1 500 RPM	430
7.5 HP 1 500 RPM	480
10.0 HP 1 500 RPM	615
Single Cylinder Air Cooled Engine:	
5.0 HP 1 500 RPM	480
6.5 HP 1 500 RPM	495
7.5 HP 1 500 RPM	560
10.0 HP A500 RPM	690
Double Cylinder Water Cooled Engines	
10 HP	930
13 HP	960
15 HP	990
Double Cylinder Air Cooled Engines	
10 HP	1010
13 HP	1030
15 HP	1060

Electrical Starters and Switches

Starters for direct-on-line or manually operated Star-Delta models are suitable for 220 and 440 v - 50 Hz, three phase or single phase - A.C. These are built-in with over load and single phase protection with bimetal relay arrangements, silver oxide bimetal contacts and other standard features to protect the electric motor from varying supply conditions.

Product	**Average Price FOB Durban $**
Three Phase Direct ON line starters to suit 3 to 10 HP range	39
Single Phase Direct ON line starters to suit 0.5 - 2 HP range	24
Star Delta air break manually operated motor starters 3 to 10 HP range	58
12.5 - 15 HP range	64

Star Delta Oil dash pot manually operated motor starters	
3 - 10 HP range	101
12.5 - 15 HP range	106

Three Phase Iron clad switches (rewireable):

Capacity rating	**Average Price FOB Durban ($)**
16 amps	16
32 amps	30
63 amps	69
100 amps	140

SPARES, ACCESSORIES, AVAILABILITY AND SUPPLY

For each pump, a trouble shooting and repairing manual, installation and maintenance hand book and spare parts catalogue is supplied to help the customer understand the procedure to follow in dismantling, reassembling and ordering spare parts. Centrifugal, monoblock, jet and submersible pumps consume minimum spares during their lifetime.

The manufacturer will specify the required spares for each pump or batch of pumps ordered and these spare parts, can be supplied with the consignment. As most of the items are in regular production, any requirement can he met at short notice and delivery can be arranged.

SERVICE ASSISTANCE FOR INSTALLATION AND MAINTENANCE

Centrifugal pumps are easy to install and run. For submersible and jet pumps, an installation guide book is provided with each pump.

Proper training can be provided for a few mechanics at the suppliers' premises. SITARC will also have training facilities for pump assembly, testing as well as installation techniques which can also be utilized.

Further a few engineers can be made available to train local people at various centres by organizing seminars and classes.

JOINT VENTURE WITH LOCAL PRIVATE PEOPLE

In India economic reforms have been in progress since 1991. Joint ventures, either in India or with African countries are encouraged, depending on the requirements. Joint venture in Africa is possible when the requirement of pumpsets by value is US$ 3 to 4 million per year. Interested parties can contact SIEMA.

CONCLUSION

It is hoped that the above information is useful. The similarity between India and Southern and East African countries in respect of soil, monsoon pattern, climate, water table, literacy levels, electric system and user method, makes Indian pumps ideal one for African countries.

ANNEXURES

1) Performance curves for single phase monoblocks

2) Performance curves for three phase monoblocks

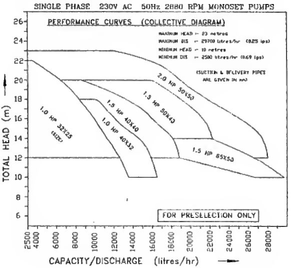
3) Performance curves for submersible pumpsets

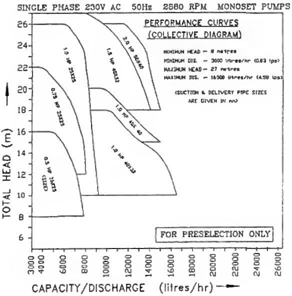
   i) Radial Flow Pumps
   ii) Mixed Flow Pumps

Acknowledgements

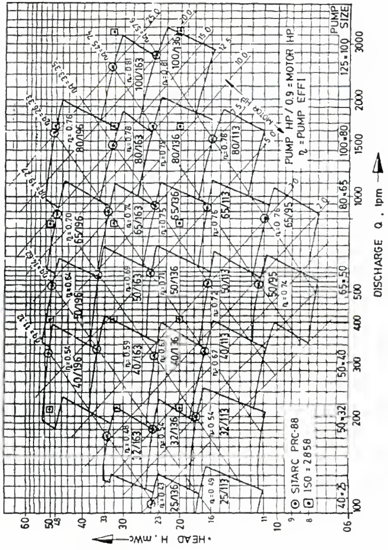
SIEMA is grateful to FAO for providing the opportunity to present their industrial scenario to the developing countries in Africa. Members of SIEMA also express their gratitude to Dr. R.K. Sivanappan for his cooperation and support without which this presentation would not be possible.

PERFORMANCE CURVES FOR SINGLE PHASE MONOBLOCKS



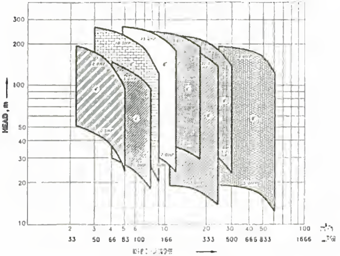


PERFORMANCE CURVES FOR THREE PHASE MONOBLOCKS

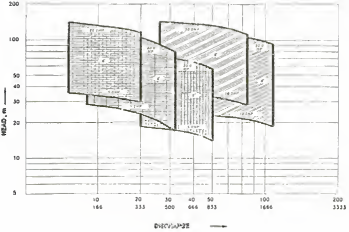


PERFORMANCE CURVES FOR SUBMERSIBLE PUMPSETS

SUBMERSIBLE PUMPSET
RADIAL FLOW PUMP SELECTION CHART



SUBMERSIBLE PUMPSET
MIXED FLOW PUMP SELECTION CHART



Review of the irrigation equipment manufacture and supply sector in South Africa

A wide range of irrigation systems is currently in use by small-scale irrigators in South Africa (De Lange, 1994). Irrigation schemes largely use sprinkler irrigation, while independent farmers with community gardens often use short furrows.

Availability of Irrigation Equipment for Small-Scale Farmers

The irrigation equipment needed for the systems in Table 1 (apart from sprinklers which are imported) is manufactured in South Africa. It is important that installations for small-scale farmers comply with the requirements as set out by Breuer and Netzband (1980):

- low level of capital costs
- use local materials where possible
- employ local skills and labour
- scheme small enough to be affordable and manageable by a small group of farmers
- user friendly technology, compatible with local values and preferences, and based on traditional methods
- easy to operate and maintain at village or community level
- minimum dependence on outside help
- involving renewable energies such as wind, sun, animals, rather than oil and electricity
- system to be erected in stages to eliminate or rectify possible mistakes and made flexible to address changing situations

Recently a number of manufacturers have developed manually-operated and small motorised pumps which are ideally suited to small-scale farming. Further development may be realised, depending on the demand by small-scale farmers. The Agricultural Research Council (Silverton) has developed a pump specifically suited to the needs of small-scale farmers using secondhand parts.

Supply of Irrigation Equipment to East and Southern African Countries

Export of products to other African countries is difficult due to design, knowledge and financial shortcomings. Suitable dealers, irrigation merchants and extension officers with the

F.H. Koegelenberg
Irrigation Engineer, Department of Agriculture, South Africa

expertise to handle even conventional irrigation systems are hard to find. South African manufacturers prefer using local agents (wholesalers or designers) when dealing with other African countries.

Joint ventures for supply and design would be possible provided that locals can be trained as technicians to supply the data. The following are some of the data:

Soils: Water-holding capacity, major soil types, irrigability, infiltration rate, typical problem soils.

Crops: Water requirements, effective root depth, compatibility to soil, climate and water.

Climate: Rainfall, temperature ranges, humidity, wind, evaporation rates.

Water: Availability, seasonality, quality, storage.

Topography: Suitable gradients, limitations on systems.

Management: Elements of irrigation management, levels needed for different systems, typical problems.

Environment: Resources conservation, pollution risks, damage, theft.

Domestic/cultural aspects: Time available for irrigation, limitations for female farmers, special days, other influences.

At this stage, production by local manufacturers is limited due to the small quantities of equipment in use in these areas. South African manufacturers would be willing to have their equipment manufactured under licence in other countries.

Quality, Performance and Cost of South African Equipment

South African products are of high quality and have been tested to give trouble-free service when applied locally. Most irrigation products are tested at the Agricultural Research Council, Institute for Agricultural Engineering, at Silverton. Test results indicate which products are suitable for use by small-scale farmers. Furthermore, most products comply with South African Irrigation Institute (SABI) and ISO quality standards. Manufacturers conduct their own factory tests and make use of the CSIR and testing facilities at local universities. It is important to use quality products with a service life of at least 15 years.

Irrigation performance is measured according to correct design, maintenance and management standards. Members of the SABI in other countries are bound by an ethical code to design systems which comply to certain norms. It will be a challenge to develop norms specifically suited to small-scale farming.

Most irrigation materials are delivered FOB Johannesburg by South African companies while CIF deliveries are also possible, if preferred, by agents in other countries. Although packaging costs are low in most cases, some companies want to make a profit on packaging as well. Depending on the size of the system, the cost of delivered equipment on farm should be about 15 to 30 percent higher than retail in South Africa to allow for merchants' profit.

Package deals can be negotiated for certain areas. For instance, a complete sprinkler irrigation system with pump can be designed and delivered, provided local technicians are involved.

Supply of Spares, Servicing and Assistance with Installation, Operation, Maintenance

Agents of South African companies can keep stocks of spares and complete equipment available for rapid replacement when problems occur. Faulty equipment will then be returned to the manufacturer in South Africa. Furthermore, South African manufacturers can visit their agents on short notice if problems arise with certain equipment. Agents are trained in the operation and maintenance of equipment and to deliver a service to farmers if problems arise.

Manuals on the operation, installation and maintenance of different equipment are available to the agents. Many manuals have sketches which simplify interpretation by clients.

It is also possible for a South African manufacturer to visit a farmer with the agent, when needed.

Advantage to Farmers in Using South African Equipment

- Equipment has been developed for African conditions especially variations in temperature and water conditions.
- Equipment is readily available due to short delivery periods.
- Distances are relatively short, making communications easier (e.g. with nstallation difficulties).
- South African manufacturers have agents who supply after-sale service.
- Most South African manufacturers are SABI members and therefore committed to the ethical code. Manufacturers gain expertise by regular communication with other SABI members.
- South African products are affordable in other countries due to the favourable exchange rate and low transport costs.
- A fast, efficient service is ensured as South African manufacturers have sufficient stocks, making products available on demand.
- The test results from Silverton can be used in comparing South African products.
- South African manufacturers are prepared to make specific one-off products provided that clear guidelines are provided.

Conclusion

South African companies have the capacity to manufacture relevant and suitable equipment for small-scale farmers in other parts of Africa. They would be willing to supply the required high-quality equipment at reasonably low costs as well as provide agents with the necessary assistance in installation, operation and maintenance of systems. They would also guide the agents to ensure that equipment supplied, is used within its limitations (working range). New equipment for which a need arises, can also be developed.

Successful irrigation by small-scale farmers, irrespective of the system or equipment used, can only be achieved using a multi-disciplinary approach, with community participation and transfer of skills. All sections of the community must actively participate from the planning, design and construction stage, through to the operation, management and maintenance stage of the scheme. It is therefore recommended that a local irrigator be trained as a technician and facilitator between the farmer and the supplier.

Planning guidelines, design criteria for small-scale irrigation systems and equipment must be drawn up for a region to ensure that the available water is used effectively. SABI can be of assistance in establishing norms.

Finally, all role-players including manufacturers, suppliers, designers, scientists, government institutions, NGOs and farming groups in East and Southern African countries must network to ensure that the relevant knowledge of the suitability of equipment remains intact and to identify shortcomings.

REFERENCES

Alberts, C. 1996. Die benutting van 'n wawiel-sisteem vir die kweek van groente en druiwe. *S.A. Irrigation*.

Breuer, A. and Netzband, A. 1980. Small-scale irrigation. *German Appropriate Technology Exchange (GATE)*.

De Lange, M., 1994. Small-scale irrigation in South Africa. WRC, Pretoria.

De Lange, M. 1995. Irrigation opportunities in a changing Africa. *S.A. Irrigation*.

Vaishnav. T. 1991. Training engineering supervisors for small-scale irrigation development in Nigeria. *Waterlines* 9(4).

Review of the irrigation equipment manufacture and supply sector in China

GENERAL SITUATION OF CHINA'S IRRIGATION

China is situated in East Asia, with high terrain in the west and low in the east. Two-thirds of China comprises mountainous and hilly areas which are distributed as follows from west to east: Qinghai Xizang Plateau, Yunnan Guizhou Plateau, Loess Plateau, Inner Mongolia Plateau, Jiangnan Hills, North China Plain and Northeast China Plain.

China's total area is 9.6 million square kilometres. Thirty-three percent is mountainous, 26% plateau, 19% basins, 12% plains and 10% hilly areas. In one word, two-thirds of the country's total area is mountainous and hilly.

China is vast with temperate and tropical climate stretching from north to south. Most of the areas have an East Asian monsoon climate. In the north of China's Heilongjiang province, there is no summer while Hainan is blessed with summer all year round. Rainfall distribution is uneven both in terms of areas and seasons. Annual rainfall ranges from 1 500 mm in the south east coastal areas to less than 50 mm in the interior part of the Xinjiang region. There is little rainfall from November to March. Seventy to eighty percent of the national rainfall is concentrated in the period from June to September and is the cause of great difficulties for the development and utilization of water resources.

China has a population of 1.2 thousand million with 80% living in rural areas. Arable land area totals 130 million hectares, with a per caput arable land area of 0.11 ha. Owing to the special geographical conditions, 70% of China's people are distributed in the eastern part of the country. The middle and lower reaches of the Yangtze river, North China Plain and South China are the most populated areas. These areas are the country's industrial and agricultural bases. As a result of high population density, the land is very precious. Production of sufficient grain and other agricultural products on limited land is therefore crucial to the maintenance of China's sustained development.

Self-sufficiency and surplus in grains is one of China's main policy goals. Consequently, the Chinese government pays great attention to agriculture. The country's major grain producing areas (plain areas) all suffer from a shortage in rainfall as indicated in Table 1. Drought is the most limiting factor affecting grain production. The development of irrigation is therefore essential for securing grain output.

Zhou Weiping
China Irrigation and Drainage Corp., Ministry of Water Resources, Beijing, People's Republic of China

TABLE 1
Characteristics of precipitation for three irrigation zones in China

Irrigation zones	Regions	Location of rainfall stations	Precipitation in different periods (mm) Annual precipitation	June to Sept.	March to May	Oct. to Feb.
Perennial irrigation zone	Northwest China inland and the middle reach of Huanghe River	Jiuquan	84	56	18	10
		Yinchuan	202	146	36	20
Unsteady irrigation zone	Huang-Huai-Hai Plain Northeast China	Dezhou	573	446	73	54
		Huaiyang	879	514	203	162
		Harbin	559	431	75	53
		Shenyang	702	509	110	83
Supplementary irrigation zone	Middle and lower reaches of Chang-jiang River, Zhu-jiang and Minjiang River, partial southwest China	Yichang	1 145	509	286	186
		Guangzhou	1 648	902	508	238
		Yibin	1 169	777	206	186

Currently the irrigated area in China is 53.8 million ha, representing 41% of the total arable land and accounting for 80% of the total national grain output. Irrigation is thus very important for China's grain production and the national economy.

There are five types of irrigation produced in China - reservoir irrigation, river diversion irrigation, water lifting irrigation, well irrigation and fragmentary small equipment irrigation. Among them, reservoir irrigation, water lifting irrigation and river diversion irrigation are all systems developed by irrigation project facilities. Small irrigation equipment is usually used in well-irrigation and fragmentary type irrigation. The composition of China's various kinds of irrigated areas is shown in Table 2.

Table 2 shows that the irrigated areas which use small irrigation equipment represent over 30% of the total irrigated areas, amounting to 16.7 million ha.

China's irrigation management has different forms according to the scales of projects. Generally, large irrigation projects are managed by the water conservancy departments at various government levels. Small irrigation projects such as well-irrigated areas are managed by villages, farmers' cooperative teams or individual farmers.

TABLE 2
Situation of China's irrigation

Classification	Area ($\times 10^4$ ha)	Percentage (%)
Total area of irrigation	5 380	100.0
Surface water irrigation	3 706	68.9
Groundwater irrigation	1 333	24.8
Others*	340	6.3

*Fragmentary irrigated area: small irrigation equipment is used in both groundwater irrigation and fragmentary irrigation.

Farmers in China depend mainly on agricultural production, township and village industries and small-sized processing industries for a living. They obtain enough grain for food from their limited land and sell other agricultural products. Irrigation is indispensable in their situation. Many farmers own small irrigation equipment. Even in some areas where water is obtained from reservoirs and river diversions, small irrigation equipment can be used to prevent or reduce grain losses during drought seasons. In mountainous areas, small irrigation facilities or methods are even more widely applied.

At the county and township levels, the Government has established anti-drought service teams. These teams can provide emergency irrigation services in time of serious droughts. The service teams also possess small irrigation equipment and receive government subsidies to assist them in their work.

CHINA'S IRRIGATION EQUIPMENT INDUSTRY

The manufacturing industry for irrigation equipment in China has developed gradually in the recent past. This development partly reflects the requirements of economic development in agriculture. At present, production of irrigation equipment has become an important component of agricultural machinery. A rather complete system including product research and development, quality control, after sale service, marketing and numerous other enterprises have been formed. It is very convenient for farmers to purchase and use small irrigation equipment in China. Therefore, both their production output and volume of use are considerable. Table 3 shows the ownership of agricultural machinery for irrigation in the whole country.

TABLE 3

Yeer end ownership of agricultural mechinery for irrigation end dreinage (1995)

	farm motive power for irrigation and drainage		of which: diesel engines		electric motors		farm pumps	sprinklers
	10^4 units	10^4 kW	10^4 units	10^4 kW	10^4 units	10^4 kW	10^4 units	set
National	1028.6	8048.65	487.6	3812.93	534.22	4212.02	912.65	585458

Farm pumps situation

	ferm pumps (10^4 units)			
Region	total	1.stete ownership	2.collective ownership	3.household ownership
National	912.65	11.57	168.87	732.21

Ownership of irrigation and drainaga machinery by rural households (1994 - 1995)

Item	Units	Ownership (1995)	Ownership (1994)	1995 increase or decrease over 1994	1995 increase or decraase rata over 1994
motive power for irrigation and drainaga	10^4units	816.83	769.63	47.20	6.13
	10^4kW	5352.82	5030.06	322.76	6.62

Features of China's small irrigation equipment formed in the development of the past decades

- **Complete types.** China can produce a wide range of small irrigation equipment. This equipment includes all types and specifications of pumps, small diesel engines, metal and plastic pipelines which are currently available in the world. Additionally, some simple equipment such as hand pumps are also produced to meet different user needs. Among the small irrigation equipment produced by China at present, the major products are water

pumps, small motive machinery, pipelines, sprinkler and drip irrigation equipment. China has also produced some special equipment, for example, water-turbine pumps.

- **Numerous enterprises and large output.** Statistics show that in 1995 there were 166 irrigation equipment enterprises managed by the Ministry of Machinery, with 65 000 workers and staff members. Their industrial output value for the year was 2.62 thousand million RMB yuan. The outputs are shown in Table 4.

TABLE 4
Volume of production of irrigation and drainage machinery (1995)

Name of product	1995	1994	1995 growth or decrease over 1994 (%)
Total	2 605 316	1 857 848	40.23
1. Sprinklers	54 467	79 228	-31.25
2. Farm water well drills	1 291	800	61.38
3. Total farm pumps	2 549 558	1 777 820	43.41
Large pumps (super large) (1995 = 282; 1994 = 182)	1 549	1 132	36.84
Small and medium	1 135 494	871 481	69.10
Mini-pumps	488 711	189 057	147.92
Deep-well pumps (long-spindle) (1995 = 13 774; 1994 = 14 419)	28 988	25 279	14.59
Submersible pumps	75 250	78 498	-4.14
Small submersible pumps	837 698	813 173	3.02
Water-turbine pumps	1 888	332	468.67

Statistics show that the demand of China's agriculture for small irrigation equipment increased so rapidly that a developed market has already been formed. With the establishment of the current market economy structure in China, competition among enterprises is very fierce and will be conducive to promoting technological progress in irrigation equipment.

Ample service networks: Small irrigation equipment is mainly purchased and used by rural households. To facilitate the extension and after-sales service, China has established ample product sales service networks. Three major systems are responsible for this work. One system comprises the agricultural companies scattered in all counties throughout the country. These companies are state owned enterprises of agricultural machinery, and provide sales and after-sales service. The highest level of this organization is the China General Corporation of Agricultural Machinery while its lowest level is the county agricultural machinery companies. Most irrigation equipment is sold to farmers through this system. The second system is the water conservancy service under the administration of the Government's water conservancy department. At the county level, water conservancy service organizations have been established. These service organizations provide farmers with services such as planning and design, installation, operation guidance and technical services to enable farmers to use these equipment for irrigation operations. The government has also established related agencies for strengthening the leadership in extension and services of irrigation technologies in several ministries. The third system involves production enterprises providing direct services. Enterprises sell equipment directly to farmers and provide them with services. Table 5 shows the service network of agricultural machinery in rural areas in 1995.

TABLE 5
Service network of agricultural machinery in rural areas (1995)

Item	Units	Township shops	Village group shops	Repair households
Number of repair shops		21 070	11 511	156 442
Year end number of employees	person	106 059	34 871	331 549
repairmen		71 529	26 191	259 661
technicians		22 533	5 619	54 208
Facilities		107 541	32 085	370 820
Processing and forging facilities	unit	27 757	6 912	68 848
Special repair equipment		52 869	17 438	192 051
Testing equipment		11 566	2 551	26 200

Effective research and development system. In China, the government pays great attention to technological progress and allocates special funds every year for research and development. Since 1996, the State Science Commission has allocated 30 million RMB yuan for research and development on water saving irrigation equipment. The state has established special research academies to conduct basic theory research and development of new products. More than 100 scientific research institutions in China are engaged in research related to small irrigation facilities and equipment and in the solution of technical problems in extension work. In addition, enterprises also invest huge amounts of capital for improving their products. The research and development efforts greatly promote technological progress of small irrigation equipment.

Effective work of the state technology inspection control system. There is a complete system of standards. There are national standards or industry (ministerial) standards for every kind of product and service. Enterprises also have their own standards. Then there is a product quality certification system. The certifying institutions designated by the State test and issue certificates on every kind of product on sale. There is also a set of quality control systems. Government has established technical inspection institutions at national, provincial and other levels. They can inspect the quality of products by sampling at any time, publish the results in newspapers, magazines and other media and make recommendations to users. Finally, enterprises have their own quality inspection units to ensure product quality.

Great government concerns. The mechanization of agriculture is a target of the Chinese Government. Government institutions play a forceful role in striving to achieve this target. At present, relevant departments of six ministries at the central level are working in areas such as machinery production, sales, services, circulation and technologies to advance the mechanization process. Furthermore, the state comprehensive departments such as the Ministry of Finance, the State Planning Commission, the State Science Commission, the State Economic and Trade Commission, the State Tax Administration Bureau and banks carry out different functions and responsibilities. Owing to the importance of irrigation and drainage services to farmers, the state has favourable taxation policies and reduced product prices. For example, the State generally stipulates a value added tax rate of 17% for industrial and commercial enterprises. However, a rate of 13% has been adopted for enterprises engaged in the production of irrigation equipment. Enterprises selling such equipment are tax exempt. Favourable tax policies are also extended to the foreign investors investing in farm machinery and agriculture.

Due to the above-mentioned factors, production and sale of irrigation equipment are very active. The domestic market situation of irrigation and drainage machinery in 1995 was better

TABLE 6
Output and sales volume of irrigation and drainage equipment (1994, 1995)

Classification	1995	1994	1995 increase or decrease rate over 1994	Annual sales volume
Machinery for irrigation, drainage & water conservancy	55 865	80 136	-30.29	60 021
portable sprinkler set	54 467	79 228	-31.25	58 484
farm well drills	1 291	800	61.38	1360
Total number of farm pumps	2 380 026	1 635 163	45.55	2 221 295
large	1 549	1 132	36.84	1742
super large	262	189	38.62	270
small & medium pumps	1 135 494	671 481	69.10	1 059 193
mini-pumps	468 711	189 057	147.92	422 509
deep-well pumps	28 969	25 279	14.59	27 698
long-spindle deep-well pumps	13 774	14 419	-4.47	13 725
submarsible motor pumps	1 039 755	920 853	12.91	977 388
submersible deep-well motor pumps	75 250	78 498	-4.14	89 596
small submersible motor pumps	837 698	813 173	3.02	788 020
water-turbine pumps	1 888	332	468.67	1 709

than 1994 and has an annual sales income of 2.384 thousand million RMB yuan, a growth rate of 24.17% over 1994. Products which sold very well include water-turbine pumps, well drills, small, medium and large pumps. The sales volume of long-spindle deep-well pumps and portable sprinkler sets declined. The imbalance in sales for different enterprises widened. Domestic production and sales of irrigation and drainage equipment in 1994 and 1995 are shown in Table 6.

TABLE 7
Export situation for farm machinery in 1995

Areas	Export value (in US$ 10 000)
Asia	32 060.1
Africa	1 803.3
Oceania	255.3
South America	1 842.8
North America	3 872.5
Europe	2 161.0
Total	41 995.0

China is paying great attention to the international market. In 1995 sales in the international market continued to grow and were better than in 1994. The value of exported goods (irrigation equipment) in 1995 reached US$ 26.45 million. The volume of export of farm pumps increased considerably. The major areas for export are some countries in South Asia, Southeast Asia and Africa. Table 7 shows the export situation for farm machinery in 1995.

Factors influencing the market of irrigation equipment.

The first of the factors influencing the market of irrigation equipment is the growth of demand in rural areas. As a result of the opening of the Chinese economy and associated reform policies, growth has been high. Living standards in rural areas have improved as well as farmers' purchasing power. Furthermore, farmers' desire to improve their production conditions has become increasingly stronger. The second factor affecting the market of irrigation equipment is the government's attention to agriculture. In recent years, the central government has increased agricultural investment and loan programmes, which have been directly transformed into demands for agricultural production materials. The third is climate. In China, many areas, big and small, frequently suffer from drought every year. In cases where drought is nationwide or affecting large areas, sales of equipment increase

considerably. The fourth factor is the formation of a complete system, including production, sales, services and technical security, which is conducive to market development.

In spite of China's above-mentioned achievements, the potential market demand is still very large. Water shortage, population growth, improved living standards, development of new agricultural production bases and updating old equipment are all factors in the promotion of production growth of irrigation equipment.

FACTORS INFLUENCING PRICES OF IRRIGATION EQUIPMENT

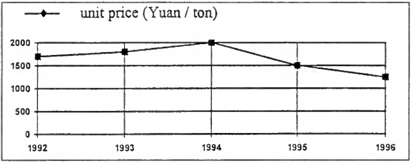
Compared with other countries, the prices of Chinese small irrigation equipment are very low. The factors which influence these low prices are analysed below.

Labour cost

This is a very important point. For small irrigation equipment, for example metal products, the proportion of labour costs is usually 20 - 40% above of the total price. This proportion reflects the low level of automation of the factories. However, in most areas in China, labour costs are very low, bringing down the product prices.

Raw materials

In China, metals such as steel, iron, copper and aluminium, which are used for the manufacturing irrigation equipment are all domestic products. In recent years, price changes of raw materials have been very unstable due to the fluctuation of demand. The following chart shows price changes for aluminium:



The chart indicates large price changes. A similar situation occurs with steel products. Such changes exert great influences upon irrigation equipment. It should be noted that in China the prices of plastics and heavy metals already approach international market prices and are, in fact, influenced by the international market. Therefore, the prices of irrigation equipment in China are clearly related to the prices of raw materials.

Government incentives

Government incentives for irrigation equipment are as follows:

- low interest loans to factories and users;
- tax reductions and exemptions, with different production, marketing and export policies;
- rice inspection, (sometimes compulsory); high price increases by factories is not allowed;
- funding for extension services to reduce staff dependence on enterprises;
- equipment subsidies for farmers; and
- financial investment in research and development activities.

These government actions have helped to reduce equipment prices and enabled farmers to purchase more equipment.

Market competition

In China, the framework of market economic structure has been initially shaped. The market has already played the major role in regulating most of the industrial products. In China, many enterprises produce irrigation and drainage equipment. Product prices are usually reduced to attract users, to compete for market share and expand sales. Consequently, product prices and factory profits decline. This decline is favourable for farmers.

Low price of irrigation equipment does not only reflect low costs but is partly a result of factories sacrificing their profits to be more competitive. Under circumstances of low prices, factories have to reduce production costs if they still want to secure some profits. Factories must, therefore, effect economies of scale. Most of the enterprises producing irrigation equipment in China are small to medium sized. Enterprises are increasingly becoming more aware of the importance of alliances and economies of scales and are therefore encouraging intensified development. This intensified development is important for the reduction of irrigation equipment prices.

Other factors

Climatic conditions, grain prices and speed of economic development are all influencing the equipment prices.

Analysis and recommendations for improving the supply of small irrigation equipment in Southern and East Africa

There are many kinds of small irrigation equipment. Differences exist in technical complexity, production conditions and use and management requirements. Equipment varies from the simple (such as hand pumps) to the complex (for example, submersible motor pumps). Effective improvement of the local supply of irrigation equipment is related to the type of equipment, market, industrial base, service system and government intervention. The following is a discussion of the advantages, weaknesses and the conditions necessary for several forms of supply.

Import from abroad

Importation is necessary under the following circumstances: (i) there is market demand but no ability to produce the equipment locally; (ii) the quality of imported equipment is good and the price is lower than on the local market or is acceptable; (iii) new equipment never used in the locality is introduced; and (iv) equipment is obtained through international assistance. The advantages of importing from abroad include: (i) avoiding additional industrial investment in the production process; (ii) removing pressure on managerial and technical staff of production sectors; and (iii) flexibility in adjusting types and quantity of products.

Limitations of dependence on importation include: (i) the enterprises are not sensitive enough to the response to their products on the market because the production enterprises are located overseas; (ii) steady supply depends on the overseas enterprises; (iii) foreign currency has to used; (iv) development of national industries may be negatively affected and (v) tariff and transportation costs increase equipment prices.

Local production

Production of small irrigation equipment should be localized to ensure a stable solution to supply equipment in the long term. This is the ultimate long term and stable solution to the supply problem. If conditions and the requirements for the establishment of local production systems for various equipment are different, the time for completing the process of localization is also different. Some products can be localized relatively quickly, e.g. water transmission pipelines for (including cement pipelines and plastic pipelines) simple hand pumps and water hammer pumps. Other products require specialized industrial equipment, e.g. submersible motor pumps, pump units driven by diesel engines and more complicated water pumps. The manufacture of these types of pumps also requires skilled professional staff and decision-making of investors.

Provided the technical and managerial conditions exist, another very important issue is the market. The absence of a large enough market as a supporting condition means that investment in local production is not good. With respect to Southern and East Africa, it is very important to form a common market through coordination among concerned countries. These countries can quickly form the regional production bases and thus promote the localization of production of irrigation equipment. If this action is only limited to a particular country in Southern and East Africa, however, local production will develop slowly due to the limitations of the national market. One way to complement investment returns is the provision of government subsidies.

Another condition required for local production is the establishment of product research and development. If there is a limited selection of equipment in the region, careful research and study of the use of existing technologies in other developing countries, which have accumulated successful experiences, is very necessary. In fact, the research and development costs of all products from the very start are rather high and are not necessary at all if this approach is not used.

Suitable technologies can be introduced into the local enterprises through technology transfer arrangements. Technology transfer can help to avoid duplication of efforts in research and development and requires less investment. The success of technology transfer is based on one condition - that the local scientific and technical staff are familiar with the situation of small irrigation equipment of other countries, the advantages and limitations of these equipment and understand how to adapt the transferred technology to the local conditions. This familiarization requires a large amount of effective information and practical experience.

Role of the government

Production of small irrigation equipment is a commercial activity, while agricultural production and the improvement of rural living are social activities. The Chinese experience indicates that the government should take greater responsibility for this work.

- **Tilting policies.** Various measures for the promotion of agricultural production should be included as important components and guidelines of the government. Under the guidance of this general principle, they should be reflected in the concrete policies in science and technology, industries, agriculture and finance.
- **Establishing a service system for the extension of science and technology.** The task of the extension of irrigation technologies is to direct farmers to master new technologies and equipment, improve the conditions of agricultural production and achieve the aim of raising grain output. The focus of this non-profit activity is to establish expert networks and organizations in rural areas to provide services to farmers.
- **Financial assistance.** Financial support is important for farmers to help them to easily accept new equipment and reduce their burden. There are many approaches through which government can provide farmers with financial support.
- Efforts should be made to **create an "attractive" environment** for foreign investors to promote capital and technologies to quicken the pace of technology introduction.
- **Cooperation among countries in the region.** Exchanges in technologies, equipment, staff and information should be widely encouraged to form a common market.
- **Staff training.** Related special programmes should be set up in special schools, universities and research institutes to train different levels of technical staff. Research should be conducted on application and work done on extension and the formation of a team of experts.

Recommendations

- Irrigation experts, government officials, staff of enterprises and other institutions should be organized by UN organizations, regional organizations or through bilateral arrangements to engage in technical exchanges on the technologies and applications of small irrigation equipment. In particular, study tours should be conducted to other countries so that there is cooperation on the content, objectives, methods, direction of technological development and product choices of the major types of equipment.
- Demonstration areas of different types of equipment from other developing countries can be established in the region to provide local farmers with an opportunity to observe the effects of these small equipment and arouse interest to try out the equipment. Training bases can be situated nearby to provide farmers with training.
- Under the support of the United Nations or other international organizations, training courses, workshops can be conducted in the developing countries with the relevant experiences. Experts can be invited to give lectures to local participants, visit facilities and train local technical extension staff.
- International financial institutions should provide assistance for this activity.
- Governments in the region should make requests to countries with which they share experiences and develop relationships to promote technology transfer through inter-governmental arrangements.
- The United Nations organizations, especially FAO, should continue to encourage the development of the whole process, formulate further actions and programmes, and guide more governments, enterprises and groups to participate in this programme.

The experiences of IDE in the mass marketing of small-scale affordable irrigation devices

Food security is a major concern for most developing nations. The ability to feed all its people is a desire that every country's leadership envisions as a major legacy. Hunger and malnutrition still plague millions of people.

Increased agricultural production will put more food on the table, decrease hunger and bring food security closer to being a reality. One of the major ways to increase agricultural production is to provide irrigation in areas hitherto not irrigated or to provide dry season irrigation to areas that only grow crops through rainfed irrigation.

A number of irrigation technologies exist: drip, sprinkler, deep tube wells, shallow tube wells, low lift and mechanical pumps, wells and dams. These technologies are all part of the solution. This paper examines one solution - low lift treadle pumps, which work from tube wells or standing water sources.

The introduction of affordable, small-scale, sustainable irrigation technologies requires two elements: suitable affordable technology and a successful mass marketing strategy and programme. Both elements are essential. Both require time, constant effort and continuing evaluation. One without the other will not produce the desired result. Technology without a mass marketing programme will not reach the vast numbers of small farmers who need water for irrigation. A marketing programme without the right technology will not accomplish the task either. A successful programme requires a workable amalgamation of the two elements.

TECHNOLOGY

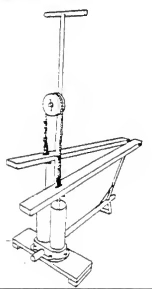
The technology of small-scale irrigation pumps exists and has proven successful in various parts of Asia, Africa and Latin America over the last fifteen years. There are various types of pumps, each with a specific use. Using the correct pump is a major part of a training programme for both farmers and technicians. [In north Viet Nam people did not need an irrigation treadle pump but a cast iron hand household pump for drinking water and supplying water to small household gardens. Quantity of water was not an issue nor was prolonged daily use because of the small plots and year round minimal rainfall. Demand was for cast iron pumps despite the fact that the treadle pump were better and less expensive.]

Treadle pumps come in various types, sizes and are made of diverse materials. The three most common types of treadle pumps are:

Lawrence A. Egan and staff of International Development Enterprises (IDE)
Lakewood, Colorado, USA

Treadle pump attached to tube well

Complete treadle pump



There are many models and sizes of this basic low lift pump. It may be made of various materials: sheet metal, plastic or cement. But all models and types basically irrigate 0.2 - 0.4 ha of vegetables or grain. The static water table must be within 7 metres of the surface.

The most common size is the treadle pump with 9 cm twin barrels. This pump produces approximately one litre a second or 136 litres a minute from a depth of 7 metres. Larger diameter 12.7 cm barrels produce more water but will only lift from 5 metres.

While this pump is normally attached to a tube well, it may also be used with an open well in dambo and other areas.

Portable river pump

This is the same treadle pump described above with a slightly different configuration for people who have a year round source of water (such as a river, lake, pond) and require a lifting and allocation water device. The pump is portable and can be moved from one location to another. It is ideally suited for areas where the soil or water tables are unsuitable for tubewells and where constant surface water sources are available.

Generally if a tube well model and a river pump work in the same area, over time the tube well model is a better choice. This choice is due to price and the availability of a constant, certain water source throughout the year.

Pressure pump

This has been successfully used on a small scale in West Africa (Nigeria, Chad, Senegal). There are several types currently used in small-scale demonstration projects in Zimbabwe, Zambia and Kenya. Currently, the Bielenberg version seems to be the best, although there is another version being developed in Kenya by Approtec.

The pressure pump is only needed in areas where the water has to be moved either from a standing water source or a tube well to areas uphill from the source for more than seven metres (23 feet). In many cases better land management or location of wells would alleviate the need for a pressure pump and permit the use of a normal treadle pump which can be placed at the top of the plot with a flexible tube from the pump to the water source. This advantage is important since the pressure pump costs on average 2-3 times as much as a treadle pump. However, in some places only a pressure pump will work.

Conclusion

Determining the right type of technology for each situation is important. However, the major task is still to be faced if there is to be mass marketing of the technology in addition to the installation of a few pumps in a few select places or projects.

Marketing

Most organizations spend the major portion of their time and effort on technology. While it is obvious that the correct technological innovation is crucial, many organizations consider the job completed once the technology is available. It is assumed that the technology will be sold without a marketing strategy. IDE's experience suggests that only a concentrated mass marketing strategy will produce a sustainable programme for large numbers of farmers.

Pumps must be marketed. The marketing process requires a sales network which includes manufacturers (large and small-scale workshops), retail dealers in various locations, teams of trained well drillers and installers and finally the customers, the farmers. The customer must be met and the utility and profitability of the pump must be demonstrated.

Even in the case of affordably designed technology, inherent constraints have often led to very poor marketing efforts. Ben Franklin once said, "the one who invents a better mousetrap will be found even in the darkest wood". With due respect to Benjamin Franklin's other contributions, such a statement is wrong: never has a mousetrap been sold without marketing.

The pumps described above (treadle pump attached to tube well, portable river pump and pressure pump) are viable agricultural products and should produce a net return of 100% in their first year of use. If the buyer requires financial assistance, this should be provided in the form of credit or an installment purchase.

Making credit available to farmers may be essential but the credit programme should be separate from the treadle pump programme one to avoid conflicts of interest. If a credit programme for agricultural products already exists, then the treadle pump should be one more item for which a farmer can obtain credit.

Government and NGOs are viewed as helpers of the poor and it is assumed that farmers cannot or will not pay. NGOs consider the people as "beneficiaries" and subsidize the product. There is a reluctance to see our target groups as "customers". In reality most poor developing country farmers are willing to pay for an affordable technology that delivers water. Various farmers in East and Southern Africa indicated that they would sell an animal to buy a pump that worked.

These are some of the reasons why so few rural products have been marketed successfully. Whether one thinks of solar heaters or agricultural implements or bio-gas plants or family planning devices, all these goods have been targeted to beneficiaries with subsidies or without sense of urgency. The approach is one of a promotional nature rather than a professional business approach, oriented to the consumer. If the design is poor or inappropriate, change is not needed as long as the promotion scheme is in place. Consequently, subsidies are increased for the very products which do not meet the needs of the customers. Instead, the suitability of the products should be improved, but this is rarely done. This is perhaps why so many development schemes fail, as there is usually little market input.

A useful rural product must be environmentally friendly and have significant advantages over competing products. The advantage may save water or labour. Such products should also in principle increase social equity or be beneficial to society.

The treadle pump is specifically geared towards the needs of small and marginal farmers and is uneconomical for a larger farmer. However, no one can guarantee that the additional income from a treadle pump is invested in the children's education or improving the quality of life of the family rather than in non-productive activities. The social awareness of the customers may be raised through NGO or government interventions. However, these

interventions are often paternalistic or are not always effective. Organizations should, therefore, develop social and gender awareness components in their marketing operations.

The following may be considered the "ten guiding principles" of a successful mass marketing programme. The emphasis here is on marketing pumps to a large number of people in a given area or country. It is not to sell a few pumps to a few people in a few selected areas or projects. The aim is to make the pumps available to as large a population as needs them. Many times an organization distributes a product in the area or to a group but often there is no large-scale marketing of the products.

Ten guiding principles of treadle pump mass marketing

Make them affordable (affordable cost): It is unfortunate that the world's best designers and engineers focus on developing products for the most affluent 10% of the world's population. Very little is geared towards mass consumption for the vast majorities of the world's population with limited purchasing power. It is a paradox of the market economy which stresses the benefits of mass consumption that there is a high competition in the successful marketing of luxury items for the wealthy few, whereas little is done to explore and penetrate rural markets with products which poor people can afford.

In Zimbabwe and other Eastern and Southern African countries, often more is done to provide agricultural implements for the large scale plantation farmer than for the poor individual smallholder.

A distinction is often made between durable and consumable goods. A durable good is one which costs several months salary or more than US$ 200, whereas a consumable is one which costs less, usually under fifty dollars. These figures apply to developed countries. In Africa the figures will be less. A treadle pump is a durable good for a farming family

One of the most important elements in the success of the treadle pump is that the cost of one installed should be less than US$ 50. This has been the experience in Asia. Fifty dollars is a significant investment for any rural family. During a two-month visit to Africa in 1996, the author after discussions with farmers in four countries, concluded that approximately US$ 50 was also a comfortable range for African farmers. The crucial price needs to be determined for Africa, but until then US$ 50 is a useful estimate.

Sell to individual farmers (target group): Another guiding principle is that the individual farming family is the prime customer. There has been a tendency to market technology to groups of people or communities. This distinction has been made because of cost and local communal systems. However, in some countries of South East Asia where there is a long local communal tradition, the individual farmer seems to want to control his or her own destiny. The farmer wants his or her own pump. Communal irrigation pumps are not popular. Deep tube wells in Asia have generally failed because organizing forty families to share the water does not work in most cases.

Do not give subsidies (non-subsidized): A major constraint for NGOs and governments is their implicit tendency to operate non-profit organizations. This tendency leads to a top down, subsidy driven approach, which views the "target population" primarily as beneficiaries rather than as customers. "Beneficiaries" perceive governments and NGOs as "free" delivery channels and consequently no-one would be willing to pay.

There is a tendency for urban bureaucrats, technical experts or politicians to make decisions for the farmer. The experts pretend to know what is best for the poor uneducated farmer. If the product is given to farmers they will not complain, even if it does not meet their needs. However, if the farmer has to pay for the product, it quickly becomes apparent whether it is needed. If it is not needed the farmer does not buy the product.

While NGOs may subsidize different aspects of its operation, the point is that the farmer has to buy the pump rather than receive it as a free gift.

Sell a viable product (viability): Any product which does not have a fast payback period is not viable. If the economic returns are only marginal then poor people will not invest money or effort, nor will they take the risks to adopt the technology. Returns must be sizeable and visible. As a general rule the pay back must be less than one year and product durability should be five times the payback period.

Use local manufacturers: To ensure long-term viability, spare parts availability and replacement pumps local manufacturers must be a part of the project from the beginning. Importation of the first 100 or so pumps is necessary but after that dependence on imported pumps or parts is not viable.

Durability and quality control are essential to this process. In the beginning quality control requires a major expenditure of effort and time. There is always going to be a tension between quality, price, demand and durability. There is no perfect solution to resolve this tension.

There must be more than one manufacturer to avoid lack of competition and one entity determining price. Hence IDE's current work in Zambia with manufacturers. It is also crucial that there be manufacturers who can make pumps available once people's expectations have been raised. [However, there are some cheap poor quality pumps in the market that only last one season or one year. Although these pumps do not fulfill quality control criteria, farmers still buy them. As the pumps are paid back in a three or four months and provide returns in the 300% range, the farmer can throw the pump away and buy a better one for the next season. This is due partly to the fact that the tubewell materials and installation cost more than the pumphead and last indefinitely. The pump head is the cheapest part of the investment.]

Work with the private sector: While NGOs and government entities have a tremendous role to play in promoting the pump, ideally pump manufacture should be in the hands of the private sector. Multiple and preferably small workshops can be the mainstay of a programme. This involvement of the private sector also supplies jobs for the local economy.

In reality only private sector entities will devote the time and energy to establish the network of dealers and well drillers since they are vital to the profitability of the enterprise. A private sector based project will go out of existence if it does not succeed. The private sector does not concern itself with blame laying if something does not sell, but rather tries to solve the problem as its economic existence depends on being successful.

A private entity also views service as a vital part of its work. If service and maintenance of its product are not available then word spreads and future sales are in jeopardy. The private enterprise does what is necessary to ensure success.

Government agencies and NGOs associate failure with experience and move on to the next project. Their existence does not depend on marketing.

Develop a critical mass: Experience has shown that sales increase exponentially, once market penetration has reached a critical mass. It is a well-known that farmers do not buy anything unless they have seen it. The best salesman for a pump is still the neighbour who has bought one.

It appears that somewhere between 20-50 pumps in a large village creates the critical mass at that level, or in a number of villages in an area or district.

Advertise: Professional type advertising and use of the mass media is vital. Besides making the product known, it also creates the image that this is a class product and not some inferior one. In Asia IDE has used videos and even soap operas to reach the wider marketplace. They have been very successful. However, the dealer network is crucial since farmers quickly get frustrated if they see or hear about the pump but it is not readily available. This is why one has to be careful about raising expectations and not being able to fulfill them. Farmers often say "You are the third (or fourth or fifth) group who has visited and talked to us. When is someone going to do something."

Provide service and maintenance: This is an area that cannot be over-emphasized. Ongoing maintenance and product improvement is essential for the long-term viability of pumps. If the farmer knows that when something goes wrong there is someone to whom he can turn for help, his confidence increases. If the product is guaranteed and service and maintenance are available, then the farmer becomes interested and will purchase.

Have a coordinating agency: There is a need for an organization, preferably an NGO, to take the lead to ensure that the pumps are manufactured and marketed. Various NGOs and government agencies will have a major part in promoting and marketing the pumps, but they need a single entity which will:

a. ensure that the pumps meet the minimum specifications;
b. train staff to market, install, and repair pumps.

Unless there is an organization dedicated to mass marketing as its exclusive objective it will be impossible to mobilize the efforts of all the government and NGO groups. There is a need for a responsible entity which has a narrow, focused concern of affordable irrigation products. The organization ceases to exist if it does not sell pumps.

However, a pump programme will always be part of another NGOs and government programme, whether for increased agricultural output or income generation. These groups need pumps that will be off the shelf items for them. There is also a need for the corporate mentality and ethos among its members. The local effort needs the support and experience from the national and international organizations.

What is needed is a focused, market driven, rural marketing entity with a human face but with organizational horsepower to reach out on a large scale. Such a body has market economy experience and a sound research and development base for continual development and service. This organization can cooperate with government, other NGOs, agencies and private sector players.

CONSTRAINTS

Lack of supply channels

In most countries moving from command to market economies, there is a lack of systematically targeted markets for agricultural implements. In the past one entity produced something and another distributed it to the beneficiary.

Experience with the treadle pump shows that a genuine interest and motivation to active rural marketing must be present, as opposed to the passive attitude that many companies use in focusing on government supplies in the past. Building rural marketing structures for low-cost products does not appeal to many due to costs and more lucrative alternative investment possibilities.

Smaller populations, higher material and labour costs in Africa will heavily affect the price of the pump and also adversely affect the supply chain.

Lack of manufacturing marketing experience

Research and development capabilities are very limited and research is often not customer-oriented. Research and development is useless unless driven by the needs of the users. Many manufacturing entities are used to being distributors rather than marketers to customers who can freely choose between different types of the same product. Rather the manufacturers have supplied the only product available and it has usually been a subsidized one.

NGOs

NGOs usually have difficulties in disseminating products on a large-scale. They tend to perceive their target groups as beneficiaries and will not charge for their services. NGOs are motivated by idealism and ideology. Their zeal to help and do something good is usually incompatible with cost recovery and profit. At times they have an anti business mentality.

Government

Government entities have the same approach as NGOs. In many transition economies the bureaucracy is overwhelming with political influence which leads to paternalism. Government officials often think they have the answers and know the farmer is unwilling to pay for something. Discussions with farmers often reveals the opposite.

International funders as well often have the same attitude. Bilateral funding often slows the process down because of its non-market approach. If funders, government and or NGOs are heavily involved, farmers have a perception that this will be a handout programme and will tend to wait before they buy.

Private sector: short term and for the few

Private sector marketing has concentrated on short-term profits and tackled the easier tasks first. They have not made the cumbersome task of rural marketing a priority. Sophisticated urban consumers appear to be an easier market than conservative, slow to buy rural consumers.

No wholesale or retail produce marketing networks

At first the additional crops grown can be consumed by the growers or sold in local markets. However, as more and more farmers begin to use treadle pumps the amount of additional vegetables and grains produced needs to be marketed. Usually the most remote farmers are the first buyers of pumps. They need roads and a rural marketing network to sell their excess produce.

Donor ambivalence to market approach

Donors and other entities often profess to be interested in promoting the private sector and private marketing efforts. However, market principles and holistic ones are not the same at all times. Some funders seem to prefer to have fifty pumps with community participation and involvement rather than a thousand pumps installed in a market context. This preference is a philosophical/theological issue. While one does not have to take either side of the issue it is good to at least recognize its influence. While succeeding in getting pumps on the ground, the market approach does not always satisfy the ideological need for holistic and integrated development required by NGOs, donors and governments.

CONCLUDING COMMENTS

Today in Bangladesh there are more than one million pumps in operation. If each pump is able to generate US$ 200 - 500 in additional wealth each year (as various independent evaluations have shown), simply by adding one winter crop which would not be grown otherwise, the concerned small farmers in Bangladesh create an extra value added equal to a quarter or half a billion dollars of agricultural GDP. This additional GDP is more than the whole modern industrial sector produces. Each farmer can grow 2 more tons of rice a year which translates into an additional 2 million tons out of 15 million tons which are grown annually.

Based on IDE's initial assessment and work in various parts of Africa, it seems clear to IDE that the potential in many parts of Africa is great. There are many areas where the existing technology can be used. In others some adaptation is needed. Generally the lesser populations will reduce the individual country mass market but selling 100 000 pumps over 5-10 years in a country with a ten million population has the same effect as selling a million pumps in a 100 million population country. But the same principles of mass marketing are involved in a country of ten million or one of a hundred million.

This paper has tried to describe the key elements of a successful mass marketing programme for treadle pumps. It is based on IDE's experience which has resulted in over 1 million pumps being sold and installed in five Asian countries in 12 years. Mistakes have been made. The paper tries to explain the reasons for success and the lessons learned. None of it is infallible and the methods can be improved. IDE would be eager to hear from others and share experiences so all can be more successful in raising the quality of life of poor rural people.

Low-cost shallow tube well construction in West Africa

One of the main constraints to irrigation development in West Africa is the mobilization of water resources and its associated high costs. At times, these costs become prohibitive, especially when groundwater is tapped for irrigation. The deeper the well or borehole, the higher the capital, operation and maintenance costs of the scheme.

While West Africa has developed only 34% of its potential for irrigation, more than 95% of the developed area relies on surface water. In view of the high evaporation rate that characterizes the sub-region, surface water is not always available at the right moment and in adequate quantity for crop requirements. Supplementary irrigation may therefore benefit from groundwater resources where economically feasible. In high potential areas year round irrigation could rely on groundwater resources, provided that abstraction remains within sustainability limits.

Traditionally, farmers lift water from shallow dug-outs and dug-wells for individually-managed micro scale irrigation in the dry season. Discharge is low and can only allow small irrigated areas. However, in Nigeria, the introduction of low-cost shallow tube well technology combined with small engine-driven water pumps triggered off the development of fadama irrigation. The total number of shallow tube wells drilled by the Bank funded Agricultural Development Projects (ADPs) in Bauchi, Kano and Sokoto State between 1983 and 1990 was over 15 000. The cost of constructing shallow tube wells was reduced by about two-thirds, with a commensurate increased return on tube well investment. In 1992 the Bank prepared a new project which would construct about 50 000 shallow tube wells in Nigeria, would privatize drilling, simplify drilling technology for shallow tube wells, conduct aquifer studies and upgrade irrigation technologies.

Relative Advantages and Disadvantages of Small and Large Diameter Wells

In West Africa, large wells are traditionally of 80 cm to 100 cm diameter. Modern large wells frequently have 140 cm or 180 cm diameter.

Theoretically, the flow of water into a well is given by the following Dupuit formula:

$$Q = \frac{pK(H^2 - h^2)}{\log_e (R / r)}$$

M. Sonou
FAO Regional Office for Africa, Accra, Ghana

TABLE 1
Relative advantages and disadvantages of small and large diameter wells

CRITERION	SMALL	LARGE
Equipment Required : (1) For Construction (2) For Raising Water	(1) Specialized equipment such as augers and bailing buckets required. (2) Specialized equipment such as pumps or small diameter well buckets are necessary.	(1) Little specialized equipment is absolutely necessary. (2) Ropes and buckets are frequently used.
Cost of Construction	Lower, because relatively little material is required.	Higher, because much more material is required.
Sanitation	Potentially good, especially when a hand pump is used.	Poor, since top of well is open. Buckets and ropes which may be dirty are used in the well
Safety	Danger during construction and use negligible.	Construction : Danger of cave-in may be eliminated by proper construction. Danger of something dropping on worker in well always possible. Use : Proper construction of top of well can minimize danger of people falling in.
Maximum Number of People Able to use the well concurrently	One	Three or Four
Rate of Discharge Possible	Potentially better since well can be made almost any depth below static water level. Good possibility of putting perforated part of casing in material of high permeability.	Depth to which well may be excavated below static water level is limited by equipment. Therefore, rate of discharge is limited.
Skill Required : (1) Well Construction (2) Water Raising Equipment	(1) Somewhat more, since tools are special and work cannot be seen (2) More, must be able to maintain and repair pump and/or small dia. Well buckets.	(1) Somewhat less. Little required
Reliability : (1) Well (2) Water Raising	(1) Excellent (2) Frequently a problem under village use (requires trained maintenance personnel).	(1) Good only if certain precautions are taken in constructing the bottom of the well. (2) Good
Ability to Store Water For Hours of Peak Demand (of Possible Importance When the Permeability of the Aquifer is very low)		May be increased by increasing the diameter and depth of well
Limitations on when well may be constructed.	None	Should be done at the time of year when the water level is at its lowest.

where Q = yield or rate of pumping (e.g. m^3/sec.)
K = permeability of the aquifer (m/sec.)
H = Static height of water (m)
h = height of water during pumping (m)
R = radius of the "cone of depression" (m)
r = radius of the well (m)

Based on the expression given above, and assuming that $R = 25$ m, that depths of penetration are the same for two wells with respectively 15 cm and 150 cm diameters. The large diameter well will yield 1.8 times as much water as the small diameter well and requires 100 times as much excavated material. Increasing depths is frequently a more efficient way of increasing the yield of a well than is increasing the diameter. However, the deeper the well,

the more difficult the working conditions during the construction phase, and the higher the costs. For large diameter wells, once the aquifer has been reached, further deepening is limited by equipment.

Table 1 (Koegel, 1985), gives some relative advantages and disadvantages of small and large diameter wells.

The decision to have a large or small diameter well will depend on many factors including:

- the geology of the location;
- materials available and their cost;
- skills available and their cost;
- the need to store water, particularly in the poorly permeable rocks where wells cannot obtain flows even in the best conditions; and
- end use of the well

In any case, two or more adequately spaced small wells will provide a cheaper and more reliable water source than a single large well.

SHALLOW TUBE WELL CONSTRUCTION TECHNIQUES

There are a variety of techniques which are used to construct small diameter wells. Table 2 provides a summary of seven such techniques.

As mentioned earlier, the deeper a well, the higher its construction costs and the cost per unit volume of water abstracted, irrespective of the type of water lifting device used. For these reasons, in West Africa, the use of groundwater for irrigation, especially from deep aquifers has not been very successful. However, over the last 15 years, shallow aquifers have been making an increasing contribution to the expansion of small-scale irrigation, particularly in Nigeria. The presence of groundwater resources at shallow alluvial depths, less than 20 metres in most of the fadamas throughout the dry season plays a key role. These aquifers are recharged annually with the onset of the rain and the river flow since they are in hydraulic continuity with the river channel. More importantly, the introduction of low-cost techniques for the construction of shallow wells has been a major contributing factor.

Five main well construction techniques are currently used in West Africa. They can be grouped under two headings as follows:

- Drilling Techniques : Small Rotary rig method
Percussion bailer (Cable-tool) method
Vibro-bailer method
- Jetting Techniques : Clear water washboring method
Mud washboring method.

Small rotary rigs

In Nigeria, most of the ADPs use small rotary rigs in drilling tube wells. This is the most versatile method since it is restricted only by hard rock formations. Drilling completion time

TABLE 2
Summary of methods for drilling small diameter wells (after Koegel)

Method	How penetration is accomplished	Minimum equipment required	Removal of material from hole	Advantages/disadvantages, limitations
Augered or bored	Cutting lips of a rotating auger shave or cut material loose from the bottom of the hole.	Auger, detachable tubular extensions, and a handle for rotating	Auger must be removed from the hole whenever it is full of cuttings. This necessitates uncoupling extensions.	Equipment is simple and can usually be fabricated or adapted locally. Cannot penetrate hard formations. Uncoupling exten-sions slows work at greater depths. Usually cannot be used below the water table.
Driven	A point on the lower end of a string of pipe allows the pipe to penetrate as it is driven on the upper end.	Drive point which usually also includes a well screen above it, special drive pipe with couplings, drive cap, and driver.	Material is not removed from the hole, but is forced through it.	Fast and simple. Special well points and heavy drive pipe may not be available locally. Hard formations cannot be penetrated. limited to small diameters, but multiple well pointsmay be connected to a common pump.
Jetted	A high velocity system of water coming out of the bottom of a vertical pipe washes away mat-erial ahead of it as it is lowered	Pipe equipped with jetting orifice(s) at lower end, coup-lings, suitable rump (hand or powered), flexible connec-tion between pump and pipe, and supply of water	The water is used for drill-ing returns to the ground surface by way of the annular space around the jetting pipe carryings the material removed with it.	fast cannot penetrate hard formations. Difficulty in bringing large gravel or stone to the surface. Drilling equipment can be fabricated locally, but a pump and a source of water are required
Hydraulic percussion	The hole is kept full of water. The alternate raising and dropping of a string of pipe equipp-ed with a cutting bit at the bottom allows pene -tration by a combina-tion of mechanical and hydraulic action	Hollow drill bit with water inlets and a check valve, string of pipe, devices to aid raising and dropping. A hand over the top of the drill pipe may be substi-tuted for the check valve.	The raising and dropping action in conjunction with the check valve causes water to be pumped up in-side of the drill pipe carry-ing the cuttings with it.	Equipment can be fabricated locally or purchased. Water is required. Traditionally used in some areas, thus understood by local well drillers. Hard formations cannot be penetrated. Difficulty in bringing large gravel or stones to the surface.
Cable	A heavy cylindrical weight equipped with a cutting edge at the bot-tom, with rope or cable attached to the upper end is alternately raised and dropped. Impact pulverized material at the bottom of the hole.	Heavy drill bit, rope or cable, devices to aid raising and dropping.	The pulverized cuttings mixed into a slurry with water during drilling. These are removed using a bailer.	All formations can be penetrated at varying rates. Some water requir-ed. Commercially built rig expen-sive and requires consider-able skill to operate, but a simple set of tools can be fabricated local-ly and adapted to man or motor power.
Bail down	A long, cylindrical bucket with a check valve at the bottom and a rope or cable attach-ed to the top is alter-nately raised and dropp-ed in a hole partially filled with water. Pene-tration is accomplished by combination of hydraulic and mechanical action	Bailer, rope, devices to aid raising and dropping.	Slurry of cuttings and water enter the bailer as it is repeatedly dropped. These are prevented from leaving the bucket by the check valve. The bucket is raised to the surface for emptying.	Equipment can be fabricated locally. Frequently used in conjunction with other methods, such as percussion. Hard forma-tions cannot be penetrated by the bailer alone.
Hydraulic rotary	A hollow drill bit with either a fixed cutting edge or toothed rollers is rotated at the bottom end of a string of pipe. Material is scraped, abraded or chipped away by mechanical action	Drill bit, drill pipe, circulat-ing pump, device for rotating drill pipe.	Water or "mud" is pumped down the hollow drill stem to lubricate the bit and to carry the cuttings up to the surface through the annular space around the drill pipe. Circulation may also be in the reverse direction.	Commercially built rig is expensive and requires considerable skill to operate. However, small adaptations using either man power or small engines have been devised. A water supply is necessary. It is difficult to drill in loose formations.

for a 20 metre deep hole is one day (Kaduna State Agricultural Development Project). These rigs are designed to penetrate to a maximum depth of 60 metres. The capital cost of a rig and associated spares and accessories is high, over US$ 50 000 (Wardrop Engineering, 1992). Due to its highly mechanical nature, a rotary rig is more susceptible to breakdown than other methods. It is likely that a finished 20 m borehole drilled by these rigs will cost around 2 000 Naira if the machines continue to be well maintained and operated. This cost compares with a few hundred Naira for a simple washbore well and with roughly 15 000 Naira for the village boreholes being installed in Bauchi State by Mitsui" (Carter, 1984).

Tube wells are drilled (in fadama) where washboring is not feasible because of the depth of the aquifer or the resistance of the overlying materials. At this stage in the development of tube wells for small irrigation in Ghana, investment in small rotary drilling equipment may not appear warranted.

Percussion bailer (cable-tool) method

The equipment is made up of a heavy drill bit, a bailing bucket consisting of a tube with a check valve at the bottom and a bail for attaching a cable or rope to the top. The method consists of alternatively raising and dropping the chisel-edged bit to break loose and pulverize material from the bottom of the hole.

The pulverized material mixes with the small amount of water kept in the hole. The slurry thus formed is removed by lowering the bailer periodically in place of the percussion bit. Drilling and bailing are alternated until the desired depth is reached. In unstable geological formations, a casing is lowered and the driving of the casing is alternated with the other two processes.

Although the method is frequently associated with large, motorized, truck-mounted equipment, it can be scaled down and used with small engines, or manpower. In the latter case, the method is still labour intensive, the equipment heavy and operations cumbersome. In the Kaduna State, Nigeria, experience showed that on average about 1 to 4 days were needed to complete one tube well in sandy soils and 4 to 6 days in clayey and gravely strata. It is less successful in strata where clayey soils and gravel are interbedded, and in basement complex with hard strata. In 1991, the cost of procuring one bailer set only was about US$ 3 700 in Nigeria. Sokoto, Niger, Adamawa, Taraba and Benue ADPs introduced manual bailer for drilling tube wells. Still, the technology is not very popular in fadama.

In Ghana, the method although tested successfully, was found slow and labour intensive, and the equipment heavy to move from site to site. Other available techniques are simpler. However, the cable-tool method may be used in conjunction with other methods when conditions such as hard or loose materials are encountered which make it more suitable.

Vibro-bailer technique

This is a combined hand augering and bailing method of drilling in sandy river beds. It is limited to shallow depths up to 10 metres and holes of 75 mm diameter. It is not suitable where layers of sand and clay are interbedded except, with use of special augers. Three semi-skilled technicians can easily be mobilized to install four tube wells per day at close locations depending on lithology.

Jetting method

The jetting technique uses a high velocity stream of water to bore the well. The stream is generated by either motor or hand powered pump. The excavated material is washed out. The erosive action of water is however ineffective in cases of hard materials. Semi-hard materials may be penetrated by a combination of hydraulic and percussion effects which are obtained by raising and dropping a chisel-edged jetting bit. Moving coarse materials such as gravel vertically out of the hole requires a greater water velocity than do finer materials. Water pressure of 3 kg/cm^2 for sand and 7 - 11 kg/cm^2 for clay or gravel have been recommended. Basically, two jetting techniques are used:

(1) Water is pumped down a jetting tube or pipe which is used inside a temporary or permanent casing. When the required depth is reached, the final casing with screen attached is lowered inside the temporary casing, which is then jacked out of the hole. Alternatively, in case of permanent casing during the jetting operation, the well screen is lowered inside the casing, which is then jacked up far enough to expose the well screen to the aquifer.

(2) Jetting may be done by pumping the water down through the casing itself. The excavated material is then carried up through the annular space around the outside of the casing.

Different versions of jetting techniques were transferred to Nigeria in the early 1980s. Three of them are presented below.

Clear water washbore method

Technique

This jetting technique uses a plastic temporary casing to support the wall of the hole until the slotted PVC lining has been placed. The temporary casing is then removed.

Technically the method appears to be quite satisfactory, except (common with all jetting methods) when penetrating clays. One solution used is hand-augering through the clay layer using a small diameter percussion tool inside the drilling pipe (having disconnected the water supply) or inside the casing (necessitating temporary removal of the drilling pipe).

In cases of jetting through fine sands, it is often worthwhile continuing to greater depth in the hope of encountering coarser material. The static water level will still rest within suction depth of surface but the yield of the hole will be significantly greater than if drilling stops in the fine material.

Materials and equipment (Kana State Agricultural and Rural Development Authority):

- Petrol Engine Pump, Fuel, Oil, Suction Hose, Delivery Hose with same specification as for suction, Strainer, Hose Couplings and Hose Clips.

- Medium Duty 2" GI Pipe 6m, 3 m & 1.5 m lengths for jetting (Total 20 m), 3" GI Cutting Edge, 3" X 2" GI Reduces Sockets, 2" GI Sockets, Bends Nipples, 24" pipe wrenches - 2 Nos.

- OPTIONAL : Water Tank, Hand Auger

Procedures

Step 1: Drill pilot hole with hand auger, removing the top clay and silt preferably close to water bearing sand. Measure the depth of water table to decide whether or not to proceed further. The depth of the water table can also be determined if a reconnaissance survey is carried out in the area to establish that groundwater is available within 6 m from the surface.

Step 2: After having established the site, decide whether to reuse the jetting water or not. If the water is to be reused, dig a pit 1 m x 1 m x 0.7 m approximately some 3 to 4 m form the pilot hole.

Step 3: Assemble the drilling pipe 3 to 4 m with GI bend and drilling bit.

Step 4: Assemble the pump with suction hose strainer and delivery hose connected to GI bend.

Step 5: Hold the GI pipe vertically with the help of a plumber and 3 labourers at the top of the test hole or about 0.5 m inside the hole.

Step 6: Start the pump. The drilling operation is performed by jetting a stream of water under pressure and washing the cuttings. Ensure all cuttings are removed before lowering the pipe further. If penetration is difficult, apply a downward reciprocating thrust by lifting and dropping the pipe continuously. By this method, it could be possible to penetrate through the lenses of clays when encountered. When the three-metre penetration is achieved, remove the 3 m jetting pipe and change it to 6 m and continue drilling, then change to 9 m and continue drilling. The change should be achieved with minimal loss of time. When penetrating the aquifer, the pipe will have the tendency to descend on its own. Examine the cuttings closely for the best available formation of coarse sand and gravel. When full depth has been penetrated either by hitting the rock or impermeable clay layer slow down the pump. The drilling pipe is then moved up and down while the pumping is continued so as to bring out all the fine material to the surface leaving the coarse sand and gravel where the screen is subsequently to be located. The pump is further slowed down.

Step 7: Assemble the PVC casing and screen to match the location of the aquifer.

Step 8: The drilling pipe is withdrawn and the assembled tube well installed immediately into the hole.

Step 9: If the hole has collapsed and the screen could not be lowered to the required level, remove the drilling bit and insert the drilling pipe close to the casing and screen and start the pump again. With the help of further jetting, lower the screen to required position.

Step 10: Cut off any length which is about 30 cm above the surface from the casing pipe and connect the PVC nipple with 2" GI bend.

Step 11: Development:- The washbore is developed by over pumping. After the development is completed, operate the pump for two hours and test the yield.

Step 12: After the tube well is operated for a fortnight, provide a concrete slab 40 cm x 5 cm around the well for permanent protection.

Advantages of Method:

1) All the materials are available locally (in Nigeria)

2) Simple technology, very cost-effective

3) No drilling mud is required. For higher depths, further improvements will be required like using a raised platform (scaffold) and using pumps to prevent holes from collapsing.

4) Excellent portability.

Disadvantages of Method:

1) A water tank pickup is required if water is not available locally.

2) If clay is encountered below a thick sand layer, the drilling could be very difficult and it may not be possible to penetrate a thick clay layer.

3) This method cannot be used to penetrate coarse water bearing sands because of lost circulation of water. As a result the tube wells cannot be completed at sufficient depth to take full advantage of the available water. For this reason, Wardrop Engineering Inc. did not recommend it for use in Ghana.

Mud washbore method (bentonite method, KNARDA):

The mud washbore method should be considered where full penetration of the aquifer is not possible with the clear water washbore method because of lost circulation in coarse sands and gravels. There are 12 basic steps involved in the procedure.

Step 1: Drill a 10 mm diameter pilot hole down to the water bearing sand using either a motor hand-powered auger. The auger hole should be drilled until caving sand prevents further advance.

Step 2: Dig pits for drilling fluid and place a screen in the flow path to remove sand that accumulates in the drilling fluid during the drilling process.

Step 3: Mix drilling mud.

Step 4: Install 50 mm drill pipe in hole.

Step 5: Circulate drilling fluid using the pump and fill the hole. Once the hole has been filled it is normally necessary to add more water and drilling mud.

Step 6: Advance drill pipe to final depth by circulating drilling mud to wash the sand from below the bottom of the drill pipe.

Step 7: Remove drill pipe and install permanent casing and screen assembly.

Step 8: Backwash through the bottom of the screen with clear water to remove the drilling mud.

Step 9: Plug the bottom of the screen.

Step 10: Develop the tube well by jetting or surging.

Step 11: Test and measure yield and water level.

Step 12: Install a cap over the top of the tube well.

The Bentonite method, although more complicated, allows one to drill deeper (12 m) than the clean water method (max. 8 m until now). The friction around the temporary casing/drilling pipe becomes very high at that depth, and with the present equipment (plastic pipes) and manpower it is not possible to drill deeper.

The use of Bentonite does have the required effect of keeping the hole open prior to placing the casing/screen. However, there are several important disadvantages associated with its use. Chief among these are costs, availability and the problem of sealing of weak aquifers so reducing yield of developed holes.

It has been suggested that commercially available biodegradable drilling muds could be used in place of Bentonite. While this would reduce the problems of clogging and development, it would still be expensive. As suggested by J.R. Temple-Hazell at the Second Fadama Seminar, Bauchi, 6-8 March 1984, it may be possible to manufacture a suitable mud locally from cowpea flour. In Ghana, bags of biodegradable mud was used per well. The cost was US$ 25 per well 1992.

Washbore with double jetting pipes (KNARDA)

A third jetting technique involves the use of dual jetting pipes (in ABS plastic) and two pumps; one of the jetting pipes has a short (0.5 or 1.0 m) stainless steel Johnson type wellpoint on its lower end and is ultimately left in place in the hole. The second pipe has an open end and is used during the jetting process only, then removed.

This method uses a pre-fabricated solvent-cemented ABS lining tube and so is less flexible in terms of depth and positioning of the intake. It is nevertheless fast and relatively simple. The method has been found suitable in river bed sands.

Washbore linings

Generally the slotted plastic borehole linings used by Bauchi State Agricultural Development Programme performs satisfactorily in shallow (less than 10 m) 4 inch holes. Slotted steel was rejected earlier on in the programme. The stainless steel Johnson type screens used by KNARDA is expensive.

Problems arise in fine grained aquifers when, in addition to obtaining low yields, there is the problem of sand pumping. Little can be done to increase yield under these circumstances, except drilling and screening a greater depth, or using large diameter structures. Alternative well-linings may be considered.

Apart from using correctly designed and installed gravel packs, the only effective way to exclude fine sand is by using fabric or fibre wrapped screens. These screens can be made from locally available materials. In India, bamboo and coir well-screens have been used successfully for some time. These well-screens are constructed by wrapping coir ropes tightly round a cylindrical framework of metal hoops and longitudinal bamboo strips; the method is described by R.G. Koegel (FAO Irrigation and Drainage Paper 30, 1985). A metal framework of a quarter-inch reinforcing rod longitudinal on metal hoops, together with hemp or manila rope, could be tried.

Shallow Tube well Programmes

Past programmes

In Nigeria, from 1983 to 1990, more than 15 000 washbores and drilled tube wells were constructed in the three States of Bauchi, Kano and Sokoto to irrigate 16 200 hectares. However, considering the 11 northern and middle zone states, more than 18 000 hectares were being irrigated with washbores and drilled tube wells. In Niger, the Lower Tarka Valley project had constructed 700 of such boreholes by 1993. The technology has also reached Chad and the northern zone of the Republic of Benin.

New programmes

The tube well and washbore technology for small-scale irrigation has proven to be very successful in Nigeria. It is much cheaper than large scale irrigation. The individual farmer's ownership of the wells and the pumpets provides considerable independence in selecting crops, cropping patterns and times of planting. It also allows adjustment of irrigation schedules in accordance with observed crop needs rather than being restricted to the strict rotation of large-scale irrigation schemes.

The success recorded by the various ADPs in Nigeria led to the National Fadama Development Project in 1992. The four year project aimed at constructing 50 000 shallow tube wells in Bauchi, Jigawa, Kano, Kebbi, Sokoto and other eligible states. The maximum irrigation potential would be 100 000 hectares. Actual realization was expected to be around 50 000 hectares. The project would simplify drilling technology, privatize drilling operations, conduct aquifer studies, upgrade irrigation technologies and organize fadama farmers for irrigation management.

The development of private irrigation in other countries of West Africa is expected to benefit from the Nigerian experience. Programmes recently formulated included 300 shallow tube wells in Niger, 100 in Burkina Faso. In Ghana, the Agricultural Sector Investment Project is currently implementing a programme of more than 2 000 shallow wells and some 100 deep wells. The washbore technique is being extensively used.

In Nigeria, the potential for shallow tube well was estimated as 237 000 hectares for the three States of Bauchi, Kano and Sokoto. Nation-wide potential is more than 2 million hectares.

Shallow Tube Well Costs

Table 3 compares some technical and economic characteristics of some well technologies. Table 4 gives the unit cost estimate of shallow tube wells. The main cost factors to be considered are:

- Capital and depreciation
- Operating and maintaining the equipment
- Performance i.e. number of wells constructed per year
- Success rate.

The last two factors depend on training and experience gained by the construction team.

In Nigeria, experience has shown that (i) a washbore could be constructed in less than half an hour under favourable conditions; (ii) three to five wells could be drilled per day using a rotary or percussion (bailer) rig; (iii) about 10 percent of the wells would be abortive.

In Ghana, the following assumptions were made:

- mud washbore method of construction
- average depth of tube well 10 metres
- 140 successful tube wells completed by each team per year; and
- overhead allowance as 50 percent of manpower costs.

TABLE 3
Technical and economic characteristics of some well technologies

	OFEDES Well f100-200 ccm	Génie Rural Large diameter well 180 cm	Génie Rural Small diameter wall 140 cm	LWR f140 cm^3 borehole (augered)	Washbore
Cost per depth unit (metre)	140 000 F	50 000 F CFA	35 000 F CFA	5 000 F CFA	5 000 F CFA
Discharge (m^3/h)	5 -20	5 - 20	2 - 10	10 - 20	10 - 20
Duration of construction	0 - 30 j (10 m)	15 - 20 j (10 m)	12 - 15 j (10 m)	1 day	1 hour
Maintenance	Vary easy	Very easy	easy	Little maintenance	Little maintenance

In the West Africa sub-region, the following unit costs can be quoted:

TABLE 4
Unit estimate cost of shallow tube wells

Country	Washbore $	Drilled tube well $
Nigeria (1992)	79	474
Ghana (1992)	313*	
Niger (1991)	200	
Burkina Faso (1995)	200	

* Details are provided in Appendix I

Conclusions and Recommendations

There are a large variety of simple, low-cost well drilling techniques. These techniques tend to be low capital and labour intensive. While each of them has its advantages and disadvantages, good combination of two or more techniques has proven very effective in overcoming some of the limitations imposed by internal or external factors as may relate respectively to the technique itself or the lithology of the well sites.

In the West African sub-region, the jetting method has a good prospect for expansion in view of the existing potential for small-scale irrigation in fadama areas. Many low-cost modifications of the basic jetting or washbore technique can be effected. It is unlikely that one universally suitable method will be found. Emphasis should be laid on methods which use locally available materials. Much effort should be put into setting up local private manufacturing firms for the equipment and the development of private contracting firms to offer washbores and drilled tube wells on a commercial basis.

References

Koegel, R.G. 1985. Self-help wells, FAO Irrigation and Drainage Paper 30, Rome.

Ghana Irrigation Development Authority. 1992. Report on Results of Demonstration Tube well Project, Wardrop Engineering Inc. June.

FAO. 1991. Projet de Promotion de la Petite Irrigation Privée au Niger, Rapport 42/91 CP-NER.23. avril.

FAO. 1992. Projet de promotion de l'Irrigation privée au Mali, Rapport 73/92 CP-MLI.35. juin.

FAO. 1995. Projet de développement de l'irrigation privée et Agro-processing, Rapport 54/95 CP-BKF.37. mai.

Report on the Second Fadama Seminar, 6 - 8 March 1984.

Siddiqi, M.R. 1991. Strategy for Fadama Irrigation Development in Kaduna State.

Sonou, M. 1994. An Overview of Low-lift Irrigation in West Africa: Trends and Prospects, 1994, RAPA Publication 1994/95.

World Bank. 1992. Staff Appraisal Report, National Fadama Development Project, Federal Republic of Nigeria. February.

Annex 1

Opening and closing addresses

OPENING ADDRESS: THE MINISTER OF AGRICULTURE, HONOURABLE DR. DENNIS NORMAN (MP)

Mr Chairman, Workshop participants, Ladies and Gentlemen

I am pleased to address you today at this workshop, which has been convened to discuss and come up with cost-effective small-scale irrigation technologies. I believe you have a challenging task ahead of you to review the current irrigation technologies and to formulate strategies to overcome problems which are being experienced by smallholder irrigation farmers.

This workshop is taking place at a time when a number of countries in Southern Africa, including Zimbabwe, have just received abundant rainfall during the 1996/97 season. As a result, waterlogging and leaching of nutrients are most topical issues raised by the farming community this season. However, we should not lose sight of the fact that a number of other unfortunate countries in the East and Southern Africa sub-region are suffering from severe droughts. Recurrent droughts and uneven distribution of rainfall are serious constraints to agricultural production and food security in many African countries. In Zimbabwe, farming activities for nearly 60 percent of the population living in agro-ecological regions IV and V are always seriously undermined by limited and erratic rainfall patterns even during a season like a current one when their counterparts in agro-ecological regions I, II and III have had above normal rainfall.

The development of water and irrigation infrastructure is therefore essential to reduce the variability of agricultural production and ensure sustainable food security in many countries in Southern Africa. It is projected that most of the increase in production required to feed the increasing world population in the next 30 years has to come from irrigated agriculture. Three critical preconditions are required to bring this about. Firstly, there must be sound investments in water harvesting and irrigation infrastructure. Secondly, good government policies are required for establishing a conducive environment for the participation of smallholder farmers. Finally, well trained farmers and personnel with adequate technical knowledge are required for the implementation and monitoring of various irrigation projects.

I understand that this workshop, jointly organized by the Food and Agriculture Organization of the United Nations (FAO) and the International Programme for Technology Research in Irrigation and Drainage (IPTRID) of the World Bank, focuses on four main themes, namely;

- *Strategies for reducing the cost and improving access to irrigation technologies for individual farmers or small farmer groups;*

- *Promotion of local manufacture and demonstration of irrigation eqnipment and provision of technical services;*
- *Low-cost water development and conservation technologies for smallholder farming; and*
- *The enabling environment for technology nptake, including credit, marketing and extension services.*

I would like to congratulate the workshop organizers because these four themes are very much in line with the critical preconditions for successful irrigated agriculture.

FAO has assisted Zimbabwe with smallholder irrigation development for a number of years. Through their assistance, Zimbabwe has developed a core of more than 40 planners and designers of smallholder irrigation schemes and implemented about 30 smallholder schemes. New methodologies in planning and implementing smallholder irrigation schemes with farmer participation, as well as water conservation technologies such as sprinkler irrigation, adapted to the conditions of the smallholder farmers, were successfully introduced and an Irrigation Testing Centre was established.

I am therefore confident that your deliberations will provide the opportunity for developing national and sub-regional programmes to promote and implement cost-effective and sustainable water conserving irrigation technologies for smallholder irrigation farmers.

It is now my pleasure to declare the Small-scale Irrigation Technology Transfer Workshop open and to wish you every success in your deliberations.

Thank you.

WELCOME ADDRESS: MRS. V. SEKITOLEKO, SUB-REGIONAL REPRESENTATIVE, FAO SUB-REGIONAL OFFICE FOR EAST AND SOUTHERN AFRICA

The Honourable Minister of Agriculture, Mr. Dennis Norman, the Permanent Secretary of the Ministry of Agriculture, Dr. Takavarasha, delegates from participating countries, resource persons, participants, ladies and gentlemen,

It gives me great pleasure to welcome you to the Sub-Regional Workshop on Irrigation Technology Transfer in support of food security on behalf of FAO and the International Programme for Technology Research on Irrigation and Drainage (IPTRID) and in my own capacity as the Representative of the FAO Sub-Regional Office for East and Southern Africa. I am glad that this Workshop, an important and probably the first technical forum to be held in sub-Saharan Africa since the World Food Summit, on a subject that is intimately related to food security and economic development, is held here, in Harare.

The most important reason for FAO and IPTRID to decide to hold this Workshop here in Harare is the unique position that our host country holds in terms of its post-independence achievements in small-scale irrigation development, and the opportunity the participants would have to visit some successful small-scale irrigation projects in the country and share the experiences of the Zimbabwean experts, equipment manufacturers and farmers in sustainable development of small-scale irrigation. This country has put in place, policies and strategies to

promote small-scale irrigation, within the framework of national development policies of the country, as a means to increase food production, achieve food security and usher accelerated economic development. Zimbabwe has established an Irrigation Technology Centre for research and testing of irrigation equipment and has adopted farmer participation, as a fundamental policy, in smallholder irrigation development; and the profitability of smallholder irrigation has been demonstrated, especially with schemes where farmers are responsible for the management of their schemes and bear all the operation and maintenance costs. Gross margins of US$ 4 000 to 5 000 per hectare per year are not uncommon in these schemes; and the importance that the Government of Zimbabwe has given to this workshop is reflected by the fact that we have today, with us here, at this opening session, the Honourable Minister of Agriculture and the Permanent Secretary of the Ministry of Agriculture. Indeed, we are privileged to have these two high officials of the government here and I wish to thank them on behalf of FAO and IPTRID for accepting our invitation to participate at this opening session of the Workshop.

Ladies and Gentlemen,

I wish to draw your attention to some important statements in the Rome Declaration of the World Food Summit, held in Rome in November last year, which are relevant to this Workshop. The Rome Declaration, which was adopted by the Heads of State and Governments who attended the Summit, considered it intolerable that more than 800 million people throughout the world, and particularly in developing countries, do not have enough food to meet their basic nutritional needs. The declaration emphasized the urgency of taking action now to fulfill the responsibility to achieve food security for present and future generations. It recognized the need to adopt policies conducive to invest in human resource development, research, and infrastructure development for achieving food security. Water control was identified as a critical element for increased and stable food production.

Recognizing the need to assist Member Nations to achieve food security, FAO, in October 1994, launched a Special Programme for Food Security (SPFS), the objective of which is to help low-income food-deficit countries (LIFDCs) improve national food security through rapid increases in productivity and food production. The goals are to maximize national food self-reliance and reduce the risk of disruptive variations in supply. Two aspects of the Special Programme are relevant to this Workshop:

(a) it gives high priority to irrigation development and water control. In its pilot and demonstration phases, the Programme features on-farm demonstrations of water management technologies and practices and assessment of the potential for low-cost irrigation and water control systems; and

(b) the Programme is designed to achieve its aims through dissemination of existing and proven agricultural technology, and the removal of constraints which hinder its adoption.

Currently SPFS is operational in 23 countries of which 12 are in sub-Saharan Africa and include countries participating in this Workshop. In addition to the Special Programme, FAO is planning to launch pilot demonstrations on water control in the remaining 60 LIFDC countries, within the framework of the FAO's Technical Cooperation Programme. It is also relevant to mention in this context that FAO and the World Bank signed a Memorandum of Understanding to launch pilot projects on small-scale irrigation development in selected

countries in Africa. The relevance and timeliness of this Workshop to the Special Programme and its related activities need no emphasis.

FAO's consistent and persistent effort to promote food security is further reflected by the theme that it has selected for the 1997 World Food Day. The theme of the 1997 World Food day is "Investing in Food Security". The role of investment in agriculture was stressed by the World Food Summit. One of the key elements of the Summit's Global Plan of Action was incentives and policies to encourage private and public investment to contribute to food security. A substantial portion of this investment will be directed towards irrigation development and water control.

Ladies and Gentlemen,

In all our endeavours, we should at all times remember that women play a decisive role in household and national food security. In rural areas, they grow most of the crops for domestic consumption and in many cases produce crops for the market as well. Despite their contribution to food security, they tend to be "invisible" actors in development. Rural women's invisibility is further accentuated by their lack of political power and social representation resulting from prevailing attitudes, gender-biased legal and social structures. These should change. Among others, technology designed to suit women's needs can contribute to mitigating drudgery and provide women with opportunity to join in more beneficial and rewarding activities including placing them as equal partners with men in small-scale irrigation.

Mr Chairman, this Workshop serves as a spring-board for action. FAO, in collaboration with IPTRID, has brought here the major stakeholders of small-scale irrigation in general and the major actors in irrigation technology transfer and adoption in particular. I should mention here, the generous financial support of the Global Water Partnership (GWP), an international programme aimed at promoting integrated water resources management, including irrigation and drainage and the principles of Dublin and Rio Conferences.

The programme of the Workshop is designed to come out with concrete recommendations for action; action by national governments, NGOs, farmers, the private sector, UN and bilateral agencies and all concerned with development. It is my hope, and that of FAO and IPTRID, that the outcome of this Workshop will be a blue print for action to promote irrigation technology for food security. With this, I wish you all the best and success in your deliberations.

CLOSING ADDRESS: THE HONOURABLE MINISTER OF LANDS AND WATER RESOURCES K.M. KANGAI (MP)

Read on his behalf hy deputy secretary (Admin & Finance), Mr. A.D. Mashanyare.

Chairman, Delegates from participating countries, Resource persons, Workshop Participants, Ladies and Gentlemen.

The Southern Africa region has experienced persistent droughts in recent years. Fortunately too, the region has been blessed with abundant rains particularly in the season just ended. There has, however, been more drought years than good rainfall years to the extent that we

now strongly believe that droughts are here to stay. Zimbabwe has not been spared from the ravages of the droughts. It has now become commonplace that all production, planning and development, particularly in the water and agriculture sectors, has to have a major focus on drought mitigation measures. I believe that both irrigation and drainage are important elements in any production system whose major thrust is aimed at minimizing the effects of the droughts.

It is also common knowledge that irrigation technologies have transformed the once erstwhile desert lands into lush green productive plains teeming with a large variety of fruit, vegetables, crops and animal feeds. The opportunities that irrigation technologies have brought about include the guaranteeing of food security at household level in the drought-prone areas to optimize land use and maximize production therefrom through double cropping or multiple cropping in appropriate areas. Such have been the benefits of irrigation that the optimum productivity of land is now being realized. Irrigation has made all the difference between starvation and survival in many parts of the world.

The increasing importance of irrigation as a means of producing both food and cash crops demands that better technologies should be developed. It is therefore significant that this workshop has concerned itself with the technological interface between the producers and the inputs into the production process, particularly water.

Water as I have said earlier is increasingly becoming a scarce commodity largely due to the drought but also due to increasing demand for its use from various users such as miners, agriculturists, urban dwellers industry, wildlife and the environment itself. It is therefore of utmost importance that water should be used efficiently. One way of inducing efficiency of water use is through the development of technologies that save water. We all know, however, that technology is user-related therefore the technologies have to be appropriate to the users.

I am informed that the transfer of improved technology for irrigation by small-scale farmers has been a major pre-occupation among you over the last four days. No doubt the recommendations that will come from the workshop will form the basis for future action to promote small-scale irrigation development through the transfer and adoption of appropriate technologies.

My ministry has long recognized the importance of water in the economy. To this extent, work is at an advanced stage to develop a water resources management strategy for the country. In the process, the legal framework is being amended to fall in line with the new economic and social order and to promote the participation of stakeholders in the planning, development, management and utilization of water resources. We hope that the recommended technologies will enable us to benefit more from the utilization of our scarce water resources.

Within the spirit of the SADC protocol on shared water resources, the Zimbabwe government through my ministry will promote inter-regional cooperation in water matters. The SADC protocol is an important political tool which will benefit a lot from improved technologies as the potential conflicts are likely to be avoided when people can adequately share a resource of such importance as water.

To all our visitors to Zimbabwe, I hope you have found your stay here enjoyable and that the workshop has met your expectations. I hope you found the exchange of ideas fruitful and that you already have something to take back home for implementation.

On behalf of the Government of Zimbabwe, I would like to thank FAO for the great honour bestowed upon us to host this joint (FAO/IPTRID East And Southern Africa) Workshop on Small-scale Irrigation Technology. We feel highly privileged to have been your hosts and we hope that you have enjoyed the hospitality of our people. We look forward to future cooperation in other fields aimed at making the small-scale irrigation schemes more efficient and more productive for the benefit of our people.

It now gives me great pleasure to declare the joint FAO/IPTRID East and Southern Africa Workshop on Small-scale Irrigation Technology officially closed.

Thank you.

Annex 2

Agenda

SUB-REGIONAL WORKSHOP ON IRRIGATION TECHNOLOGY TRANSFER IN SUPPORT OF FOOD SECURITY ***Harare, Zimbabwe, 14-17 April 1997***

Monday 14 April	
Opening Session	
Chair	**Permanent Secretary, Ministry of Agriculture, Government of Zimbabwe** Address by the Chairperson
0900 hrs	Welcome address V. Sekitoleko, Representative, FAO Sub-Regional Office for East and Southern Africa
	Inaugural address by the Honourable Minister of Agriculture, Government of Zimbabwe
0930 hrs	Coffee Break
Session II	**Technology Transfer and Enabling Environment for Small-scale Irrigation**
Chair	**V. Sekitoleko, SAFR, FAO**
1000 hrs	Objectives of the Workshop and adoption of Agenda
1015 hrs	Findings of the FAO/IPTRID mission on technology transfer A. Kandiah, FAO and R. Purcell, IPTRID
1050 hrs	
	Presentation by national consultants to the FAO/IPTRID mission
1115 hrs	Discussion
	The SISDO credit programme: an example of the enabling environment in Kenya
1140 hrs	
	M. K. Gakundi, General Manager, SISDO, Kenya Discussion
1220 hrs	
	Summing up by Chairperson
1230 hrs	Lunch Break

Session III	**Issues, and Opportunities for Technology Transfer and Adoption**
Chair	**H.W. Wolter, FAO**
1400 hrs	Introduction to the Session by the Chairperson
1405 hrs	Low-cost technology for household water and food security E. Perry, USA
1425 hrs	Discussion led by A.E. Daka, Zambia
1450 hrs	Promotion of low-cost and water-saving technologies for small-scale irrigation M. de Lange, South Africa
1510 hrs	Discussion led by M. Sonou, FAO, RAF
1535 hrs	Coffee Break
1600 hrs	Technologies for water harvesting and soil moisture conservation R. Florin, FAO, Rome (Presenting the paper of Mr. R.K. Sivanappan, India)
1620 hrs	Discussion led by R.L. Daluti, Tanzania
1645 hrs	Summing-up by Chairman
1700 hrs	End of Session
1800 hrs	Reception
Tuesday April 15	
Session IV	**Equipment manufacturers/Suppliers Forum**
Chair	**J.M. Makadho, AGRITEX, Zimbabwe**
0900 hrs	Invited Speakers: C.R.S. Sundaram, India F. Koegelenberg, South Africa W. Zhou, China
1030 hrs	Discussion
1045 hrs	Coffee Break Other Speakers: L. Egan ,IDE M. Fisher, Approtec E. Perry, ATI
1200 hrs	Discussion
1230 hrs	Lunch Break **Technical Tours**
1330 hrs	Visit to the Irrigation Testing Centre and Equipment manufacturers/Suppliers poster session
1800 hrs	Return to hotel

Wednesday April 16	**Plenary session**
Chair	**H.W. Wolter, FAO, Rome**
0830 hrs	The enabling environment for sustainable small-scale irrigation development in East and Southern Africa M. Rukuni, Zimbabwe Discussion
0900 hrs	Economics of Irrigation technology transfer K. Palanisami, India
0930 hrs	Discussion
1000 hrs	**Introduction to Working Groups**
1030 hrs to 1600 hrs	**Working Group I**: Low-cost technology for individual farmers or small group of farmers **Chair**: A. E. Daka, Zambia **Facilitators**: A. Savva, FAO, R. Purcell and F. Gadalle, IPTRID and C. P. Mzembe, Malawi **Resource Person:** E. Perry, USA **Working Group II:** Local manufacture, supply and technical services and demonstration of irrigation technologies **Chair:** R. Chitsiko, Zimbabwe Introduction to the Working Groups Coffee Break **Facilitators**: Cornish, IPTRID and H. Wolter, FAO **Resource Person:** M. de Lange, SA **Working Group III**. Appropriate technologies for water harvesting and soil moisture conservation **Chair**: M. Tafesse, Ethiopia **Facilitators**: A. Kandiah and R. Florin, FAO **Resource Person:** R. K. Sivanappan, India
1600 to 1800 hrs	**Meeting of the Core Members of the Working Groups** Drafting of recommendations of the Working Groups
2100 to 2400 hrs	**Meeting of the Drafting Committee of the Workshop** Drafting recommendations the Workshop
17 April (Thursday) **Session V**	**Plenary Discussion on Recommendations of the Working Groups**
Chair	**R. Purcell, World Bank**
0900 hrs	Presentation of recommendations of the Working Groups Discussion
1100 hrs	Coffee Break

Closing Session	
Chair	**J. Makadho, Director, AGRITEX**
1115 hrs	Address by the Deputy Permanent Secretary, Ministry of Water Resources, Government of Zimbabwe
1200 hrs	Presentation of the recommendations of the Workshop R. Florin, Rapporteur of the Workshop
1400 hrs	Adoption of recommendations of the Workshop
1900 hrs	Closing of the Workshop
	Field Visit: Visit to the Nydire 10, small-holder Irrigation Scheme
	Return to Harare

Annex 3

List of participants

NAME	ADDRESS
Amanuel, W.A.	P.O. Box 1795, Addis Ababa, Ethiopia Tel: 15 -13 - 25
Arao, L.A.	P.O. Box 58736, Nairobi, Kenya Tel: 254 - 2 - 569712
Blank, H.	P. O. Box 30261, Nairobi, Kenya Tel: 254 - 2 - 582978 Fax: 254 - 2 - 749590 email: hblank@arcc.or.ke
Bosma, A.J.	Old Mutual Centre (6th floor) J.Moyo/3rd Street P.O. Box 3730, Harare, Zimbabwe Tel: 263 4 791420, 263 4 791485 Fax: 263 4 703497 email: andries.bosma@field.fao.org
Chidenga. A.	Irrigation Engineer, AGRITEX Harare, Zimbabwe
Chitsiko, R.J.	Ministry of Agriculture, P.O. Box CY 639, Causeway, Harare, Zimbabwe
Cornish, G.	HR Wallingford Howberry Park, Wallingford, Oxon OX10 8BA United Kingdom Tel: 00 44 1491 822441 Fax: 0044 1491 826352 email: gac@hr wallingford.co.mk
Craven, R.	Cochrane Stork, P.O. Box 139, Harare, Zimbabwe
Daka, A.E.	Ministry of Agriculture, Food and Fisheries NIRS, P/B s.3 Mazabuka, Zambia Tel: 260-032 30405

Daluti, R.L.	Zonal Irrigation Unit, P.O. Box 1843 Moshi, Tanzania Tel: 255-055-50494 Fax: 255-055-50494
De Lange, M. Ms	P.O. Box 35660, Menlo Park, O102, South Africa Tel: 27-12-466332 Fax: 27-12-466391 email: ldlmdl@global.co.za
De Waard, J.	Netherlands Embassy 3 Arden Road, Highlands, Zimbabwe
Dube, L.D.	ARDA, P.O. Box CY 1420, Causeway, Harare, Zimbabwe Tel: 263-4700095/6 70584/3 Fax: 263-4-700880 email: ardah.@samara.co.zw
Egan, L.	10403 West G/FAX SCIR 500, Lakewood, C/0 80W, USA Tel: 303 232-4336 Fax: 303-232-8436 email: egant@col.com
Fisher, M.	Approtec P.O. Box 10973, Nairobi, Kenya Tel: 254-2-787380-1, 254-2-783046 Fax: 254-2-787380-1, 254-2-783046 email: mjfisher@tt.sasa.unon.org : approtec @elci,gn.apc.org
Florin, R.	FAO Land and Water Development Division Viale delle Terme di Caracalla 00100 Rome - Italy Tel: 39 6 5705 4033 Fax: 39 6 5705 6275 email: reto.florin@fao.org
Gadelle, F.	AGRPW - IPTRID ,The World Bank 1818 H St NW Washington DC 20433, USA Tel: 202 4581566 Fax: 202 5223305 email: fgadelle.world bank.org
Gakundi, M.	Muringa Road, P.O. Box 76622, Nairobi, Kenya Tel: 571348. 570280 Fax: 571531

Gessesse, H.	Water Action, P.O. Box 13367 Addis Ababa, Ethiopia Tel: 614275
Gupta, A.K.	17/1-C, Alipore Road, Calcutta, 700027, India Tel: (91-33) 479-8126/7455 Fax: (91-33) 479-7626
Hugo, L	P/B 13184, Windhoek, Namibia Tel: 09264-61-2022123 Fax: 09264-61-220367
Hungwe, S.	ZFU, P.O. Box 3755, Harare, Zimbabwe
Kalinga, G.M.	Ministry of Agriculture P.O. Box 9192, Dar-es-Salaam, Tanzania Tel: 051-117025, 0811-336435 Fax: 051-117025
Kalule-Sewali, J.B.	P.O. Box 102, Entebbe, Uganda Tel: 256-042 Fax: 256-042-21010
Kamuti, C.	Chibero College, P Bag 901, Norton Tel: 263-4-22230-8
Kandiah, A.	FAO Land and Water Development Division Viale delle Terme di Caracalla 00100 Rome - Italy Tel: 39 6 5705 4033 Fax: 39 6 5705 6275 email: arumugam.kandiah@fao.org
Kapatuka, M.	CPAR, P.O. Box 30998, Lilongwe, Malawi Tel: (265) 744315 Fax: (265) 744206
Khonje, A. T.	Ministry of Irrigation and Water Development P. O. B ox 30797, Lilongwe, Malawi
Koegelenberg, F.H.	12 Coronata Streeet, Stellenbosch 7600, South Africa Tel: 27-21-8085357 Fax: 27-21-8085370

Lovell , C.	Lowveld Research Station P. O. Box 97, Chiredzi, Zimbabwe Tel: 263 (1)31 2397-8 Fax: 263 (1) 31 2562
Made, A.	Director, ARDA PO Box CY 1420, Causeway, Harare, Zimbabwe Tel: 263-4700095/6 Fax: 263-4-700880 email: ardag@samara.co.zw
Makhado, J.	Director, AGRITEX Harare, Zimbabwe
Makonnen, Tadesse	P. O. Box 325 Aulassa, Ethiopia Tel: 201585
Mangueze, M.	Mozambique Street Resistencia No. 1746 Maputo, Mozambique
Masarira, S. Ms	Mlezu Agricultural Institute P Bag 8062, Kwekwe, Zimbabwe Tel: 155-3087
Mhondiwa, A.M.	CARE International P.O. Box 264, Masvingo
Moffat, P.C.	Ministry of Agriculture, P Bag 503, Gaborone, Botswana Tel: 267-350667 Fax: 267-307057
Moyo, N.	IDFU, P.O. Box CY 610, Causeway, Harare, Zimbabwe
Mpofu, T.	UNDP, P. O. Box 4775, Harare, Zimbabwe
Mtileni, R.	P Bag 9487 Pietersburg 0700 South Africa Tel: 0152-2957090 Fax: 0152-2957028
Mupunga, E. G.	132 Harare Street P.O. Box 1390, Harare, Zimbabwe

Mwanza, H.D.	Ministry of Agriculture, Food and Fisheries, Box 50291, Lusaka Tel: 260-1-254061 Fax: 260-1-251854
Mwathe, H. K.	Ministry of Agriculture , Livestock Production, Irrigation and Drainage, P.O. Box 30028, Nairobi, Kenya Tel: 721691 Fax: 722605
Mzembe, C.P.	Controller of Irrigation Department of Agriculture and Irrigation Lilongwe, Malawi
Ndlovu, P.	Ministry of Agriculture Esigodini Agricultural Institute P Bag 5808, Esigodini, Zimbabwe
Ndoro, J.	Netherlands Embassy, 3 Arden Road, Highlands, Zimbabwe
Ogwang, J.M.	Dept of Land Res. & Dev. P.O. Box 102-EBB (U), Uganda Tel : 042-20981/ex-20363, 20015 Fax: 256-042-21010
Palanisami, K.	Water Tech. Centre, Tamil Nadu Agricultural University, Coimbatore - 641003, India Tel: 091-422-431222 Fax: 091-422-431672 email: kpalanisami/wimbatore @dartmail.dartnet.con
Patel, R.N.	Central Irrigation Systems P.O. Box 1223, Lilongwe, Malawi
Perry, E.	1828C street, NW, Washington DC, USA Tel: 202 463-8452 email: ed.perry@ati.org
Phakati, J.B.	Kasisi Agricultural Training Centre P.O. Box 30652 Tel: 233101
Purcell, R.	IPTRID Program Office Agriculture & Natural Resources Dept. Room N-7015 The World Bank, 1818 H Street N.W. Washington DC, 20433, USA Tel: 1 202 473 5571 Fax: 1 202 522 1142 email: rpurcell@world.bank.org

Rukuni, M.	Faculty of Agriculture, University of Zimbabwe Dept. Agricultural Economics and Extension PO Box MP 187, Mt Pleasant, Harare, Zimbabwe Tel: 263 4 303211 Fax: 263 4 333407
Savva, A.	Old Mutual Centre (6th floor) J.Moyo/3rd Street Box 3730 Harare, Zimbabwe Tel: 263 4 791420, 263 4 791485 Fax: 263 4 703497 email: andreas.savva@field.fao.org
Sekitoleko, V. Ms	Subregional Representative, FAO Subregional Office for Southern and East Africa 6th floor Old Mutual Centre J. Moyo/Third Street PO Box 3730, Harare, Zimbabwe Tel: 263 4 791407 Fax: 263 4 703497
Senzanje, A.	University of Zimbabwe, Soil Science and Agricultural Engineering P.O. Box MP 167 Mount Pleasant
Sivanappan, R.K.	14 Bharath Park, 4th Cross, Coimbatore 641043, India Tel: 91-422-442555 Fax: 91-422-230928
Siziba, R.	Kushinga Phikelela Agricultural Institute P Bag 3705 , Marondera Tel: (179) 24329
Sonou, M.	FAO Regional Office for Africa, P.O. Box 1628 Accra, Ghana Tel: 233 21 666851 Fax: 233 21 668427 email: moise.sonou@field.fao.org
Sundaram, C.R.S.	Secretary, Southern India Engineering Manufacturers' Association, Coimbatore, 641043, India Tel: 91-422-440608, 442025 Fax: 422-436148

Tafesse, M.	Metaferia Consulting Engineers P.O. Box 5571 Addis Ababa, Ethiopia Tel: 251-1-517420, 251-1-515647 Fax: 251-1-514466
Takavarasha, T.	Secretary for Agriculture Ministry of Agriculture Private Bag 7701, Causeway, Zimbabwe Tel: 706081/9 Fax: 734646
Thaka, F.	Gwebi College, P Bag 376B, Harare, Zimbabwe Tel: 304515/6 Fax: 304522
Van Veenhuizen, M	P.O. Box 3730, Harare, Zimbabwe
Wake, A.	Ethiopia Social Rehabilitation and Development Fund P.O. Box 5023 , Addis Ababa, Ethiopia
Wolter, H.W.	FAO Land and Water Development Division Viale delle Terme di Caracalla 00100 Rome - Italy Tel: 39 6 5705 4702 Fax: 39 6 5705 6275 email: hans.wolter@fao.org
Yohannes, B. M.W.	P.O. Box 1048 Asmara, Eritrea Tel: 291-1-181415
Zhou, W.	Ministry of Water Resources, No 2 Lanez, Beijing 100053, Peoples'Republic of China Tel: 86 10 63203394 Fax: 86 1063203400

Annex 4

Report on discussions

MONDAY, 14 APRIL 1997: OPENING SESSION

The opening session of the workshop was chaired by Dr. T. Takavarasha the Permanent Secretary, Ministry of Agriculture. Ms. V. Sekitoleko, Sub-Regional Representative, FAO Sub-Regional Office for East and Southern Africa, welcomed the participants. She began her speech by reminding participants of the international forum such as the World Food Summit which adopted the Rome Declaration which had considered irrigation and water control as one of the priority actions in the context of agricultural development and food security, stressed the heavy task and important role given to women in this context and considered the success already confirmed by small-scale farming in the African region.

His Excellency, the Minister of Agriculture explained that some of Zimbabwe's priorities were corresponding perfectly with the objectives of this workshop, namely, investments in water harvesting and irrigation, sound water policy and training of designers and irrigators. He suggested that the often used question - *can we afford to invest in irrigation?* - had to be changed into - *can we afford NOT to invest in irrigation?*

Mr. H. Wolter, Chief, Water Resources, Development and Management Service, FAO, stressed that the workshops objective was to bring together governments, manufacturers, traders, farmers, NGOs and aid agencies to work out and define strategies to provide and facilitate access to small-scale irrigation technology. He also pointed out that the workshop was organized and financed by FAO and IPTRID with financial topping-up from the Global Water Programme.

SESSION II: TECHNOLOGY TRANSFER AND ENABLING ENVIRONMENT FOR SMALL-SCALE IRRIGATION

Mr. A. Kandiah, FAO, summarized the findings of the FAO - IPTRID mission which had visited selected countries in East and Southern Africa and was now providing the material for the present workshop. Irrigation development in Africa has expanded at a much slower rate than in Asia, regardless of the fact that countries in Africa give importance to small-scale agriculture and irrigation. The main reasons for such slow development are the fact that the costs for irrigation development in Africa is much higher than in Asia, credit facilities are inadequate, skilled labour is short and after-sales service and provision of spare parts is inadequate. The mission believed that technology transfer from Asia to Africa could improve the situation and found the following technologies appropriate for transfer: treadle pumps and other manual pumps, including animal powered pumps, hydraulic rams, motorized pumps, low-cost drilling technologies, water harvesting structures, sprinkler irrigation and micro-irrigation systems.

Mr. R. Purcell, IPTRID, reported on the developments of low-cost technologies for small-scale irrigation in Kenya where, already in the past, gravity irrigation was practised and pumped irrigation of micro schemes is rapidly developing. Simple and easily transportable, locally made, pedal pumps are sold with success on the free market at a very reasonable price (US$ 72.5 per unit) as well as locally made sprinklers.

Kenya's experience shows that while the government has an important role in supporting small-scale irrigation development, the private sector is able to promote irrigation more rapidly and without the adverse effects of subsidies.

During the discussion which followed, it was remembered that inland valley development could be another field of potential development. Some speakers mentioned the fact that quality control of local manufactured equipment was important and others raised reservations concerning the introduction of new technologies without follow-up of field applications as well as monitoring of water resources (depletion of shallow groundwater resources because of introducing cheap pumping facilities).

Mr. M. Gakundi, SISDO, Kenya, explained their credit programme which is based on the principle that credit is organized and monitored by an NGO but that credit itself is provided by local banks. Experience has shown that this system provides a much higher rate of payback than credit facilities provided directly by government. An interesting aspect of this is that SISDO requests government certification for the existence and good performance of farmer associations and an official quality certification for equipment to be purchased. The following discussion revealed that the "powerful" situation of SISDO was due to the fact that they were the only owners of equipment left for which credit had been organized until full repayment and that SISDO was charging for its services while the monitoring was still financed from donor funds. Comments from the participants indicated that the smallholder land tenure system of Kenya, based on the freehold tittle deeds, could be another good reason for the success. However the land tenure system in most African countries is based on the traditional communal system.

Session III: Issues and Opportunities for Technology Transfer and Adoption

Mr. E. Perry, USA, reported on the successful transfer of technology of the treadle pump, hand-dug tube wells, wrapped filters and wash-bowl techniques for groundwater development from Asia to West Africa. It was reported that due to the high cost of fuel, farmers with areas of up to 0.5 hectares, already owning mechanized pumps, have switched to treadle pumps. During the following discussion the importance of electrification was stressed as well as the need to accompany large-scale pump promotion with the monitoring system for shallow groundwater. It was also remembered that efficient increase of mechanized pumps could be obtained by choosing equipment with efficient and low-fuel consumption rates.

Ms. M. de Lange, South Africa, reported on the promotion of low-cost and water saving technologies for small-scale irrigation. She explained that small-scale would not represent only the size of the scheme but would also give indications on the risk factor, a one-hectare scheme of commercial flower irrigation will not be considered small-scale. She explained that South Africa was still giving importance to gravity irrigation but that they were presently undergoing considerable changes and approach as the equipment available, and in the past used for large-scale farmers, had to be adapted to the small-scale use.

Mr. R. Florin, FAO, presented the paper of Mr. R. Sivanappan, India, (absent due to an air traffic strike) on technologies for water harvesting and soil moisture conservation, underlining that soil moisture conservation was heavily related to integrated watershed management which is essential to protect the downstream irrigation schemes. He stressed that these activities required important financial investments and active participation of direct and indirect beneficiaries which is not possible without support from community and government structures. The audience was reminded that water harvesting for irrigation was usually more expensive than other irrigation developments but had the advantage of being developed in areas where no river or groundwater was available. During the following discussion it was remembered that good tank and dam sites were usually situated on communal land and that mobilization of future users for their development was more difficult than for other irrigation schemes.

In summing up the day's work Mr. Wolter, FAO, confirmed that there was a need for upgrading irrigation technology, that technology transfer should be demand driven and that access to credit and input credit had to be improved. It was understood that low-cost technology is only a starting point for development which should leave the opportunities open for upgrading and further development. The government's role should concentrate mainly on water resources assessment and development of main hydraulic structures (including dams) which required financial support. There was a consensus that watershed management and small-dam construction was not easy to be implemented at the communal level, that a certain degree of mechanization was necessary.

TUESDAY, 15 APRIL 1997

SESSION IV: EQUIPMENT MANUFACTURERS AND SUPPLIERS FORUM

Mr. C. Sundaram, Secretary SIEMA, reviewed the manufacture of irrigation equipment and supply sector of India, which produces more than 3.4 million pumps annually, of which 97 percent are electric pumps. He explained that India could offer extremely competitive prices because of its mass-production, cheap labour and in-country availability of most of the prime material necessary for production. Pump production is subject to a tight quality control system by the Bureau of Indian Standards, in fact farmers are only receiving bank loans for equipment with a BIS testing certificate.

Mr. F. Koegelenberg, South Africa, reviewing the manufacture of irrigation equipment and supply sector of South Africa, said that most of the equipment produced at present had been designed for commercial farming, and was therefore not particularly suitable for small-scale farming.

The sector is still lacking information on the demand/market situation for small-scale irrigation equipment and the manufacturers are only now starting to look into the needs of small-scale farming concerning irrigation equipment. Nevertheless, a very rudimentary mini-drip system for the use and disposal of domestic waste water and light-weight plastic flat pipes for tertiaries and main furrows have been developed and are suitable for urban/periurban and small-scale irrigation.

Mr. W. Zhou, China, presented the general situation of China's irrigation sector and, in particular, the status of manufactured irrigation equipment and supply. The sector is very

much oriented towards the national needs of irrigation equipment and its servicing networks cover all rural areas, therefore exportation of such equipment is very limited, compared to the overall production. Items of particular interest sold outside China were: turn-key mini-size, mobile sprinkler systems, small hydraulic rams in PVC, low pressure pipes and inflatable dams and weirs.

Mr. L. Egan, International Development Enterprises (IDE), USA, reported on the experience in mass marketing of small-scale affordable, irrigation, devices, mainly treadle and other manually driven pumps, explaining the approach of targeting individual farmers, manufacturing locally by the private sector and of avoiding the provision of subsidies. He underlined the importance of marketing, but stated that selling equipment and providing and administrating credit for purchase was not viable, because the latter required a completely different structure and expertise than the selling, which had to be close to the rural population. Based on IDE's experience on large-scale promotion and sales of treadle pumps in Asia and the initial assessment work done in various parts of Africa, it seems that the potential for dissemination of these simple devices on a large scale in Africa are great.

Mr. M. Fisher, Appropriate Technologies for Enterprise Creation (ApproTEC), Kenya, reported on the success of their locally constructed pedal pump "Moneymaker", of which over 1 350 units have been sold since October 1996 for a price permitting profit to manufacturers as well as provision for marketing and after-sales services, but still affordable to individual farmers (about US$ 72). He, as the previous speaker, underlined the importance of marketing and demonstration, which, according to ApproTEC's experience, should not be done at farm level only, but mainly at busy places such as markets, schools, etc. Another important issue considered is the quality control of a product/trademark, as low quality, pirate copies of the product might badly influence the marketing of the original device.

Mr. E. Perry, Appropriate Technology International (ATI), USA, reviewed their experience in Sub-Saharan Africa on low-cost irrigation technologies for food security, in particular the dissemination of treadle pumps, of hand augured tubewells and of washbore techniques for groundwater development (in Senegal, Mali, Niger and Benin). He stressed the importance to create competition among local manufacturers, in order to lower production costs, and said that the dissemination of low-cost technologies was not their final objective for development, but was only a starting point for longer-term, sustainable development.

In the afternoon of session IV, a visit to the Zimbabwe Irrigation Technology Center (ZITC) of AGRITEX (Department of Agriculture Technical and Extension Services, Ministry of Agriculture) was organized. ZITC's main functions are: the testing of irrigation equipment on behalf of the government or private suppliers, manufacturers or farmers; the development and verification of standards for irrigation equipment; and the demonstration, training and dissemination of irrigation technologies. At the same time a poster session for irrigation equipment manufacturers and suppliers was organized with the participation of equipment manufacturers from China and India, and local suppliers from Malawi and Zimbabwe.

WEDNESDAY, 16 APRIL 1997 - PLENARY SESSION

Mr. M. Rukuni, University of Zimbabwe, presented his views on creating and enabling an environment for the uptake of low-cost irrigation equipment by small-scale farmers, arguing that the future of irrigation in Eastern and Southern Africa is in smallholder production,

marketing and export of high value commodities, particularly fresh fruit and vegetables, as well as cut flowers. Consequently, policies have to shift from large to small-scale, and designs have to emphasize small, owner-operated systems.

Mr. K. Palanisami, Tamil Nadu Agricultural University, Coimbatore, India, summarized the economic aspects of the findings of the FAO-IPTRID mission in selected countries in East and Southern Africa which, as stated previously, had provided the material for the present workshop. He concluded that irrigation development, particularly small-scale irrigation, will be an important component of a diversification and expansion strategy to strengthen food security for the future and that there is a need to identify crops and irrigation techniques which will give higher returns to irrigation water and overall investment.

WEDNESDAY, 16 APRIL 1997: WORKING GROUPS FOR DETAILED DISCUSSIONS

The plenary was split into three simultaneous working groups, to discuss in detail the papers presented and contributions made to the workshop. The conclusions and recommendations of the three groups were presented in Part 1.

THURSDAY, 17 APRIL: PLENARY DISCUSSION ON OUTCOME OF WORKING GROUPS AND CLOSING SESSION

In the discussion on the findings and recommendations of the three working groups, several speakers stressed the need to improve the farmer's access to real-time information on marketing prices of crops, transport facilities to the marketing centers, credit facilities and new equipment and technologies available on the market. It was furthermore noted that, while during the present workshop only the exploitation of shallow groundwater was promoted, there would be occasions where development and exploitation of deep groundwater resources would be more reliable and still economically feasible.

The overall workshop recommendations were then presented and endorsed by the plenary, after some minor corrections and modifications. The adopted recommendations are presented in Part 1.

Finally, at 12.00 hours, the workshop was closed by the Deputy Permanent Secretary, Ministry of Land and Water Resources, on behalf of the Minister of Lands and Water Resources.

In the afternoon, there was a field trip to Nyadire where ten smallholder irrigation schemes provided the exposure of the participants to a sample of smallholder irrigation development in Zimbabwe. The scheme, which covers a total of nine hectares, apportioned to 18 smallholders, is managed by the farmers through their irrigation management committee. The farmers are able to operate and maintain the drag-hose sprinkler system, in view of its simplicity, and cover all the operation and maintenance costs. Farmers are growing a number of vegetable crops and maize, resulting in good financial returns (around US$ 2 500 per 0.5 hectare) enabling them to maintain a better standard of living from 0.5 hectare each, than their counterparts in the dryland are achieving with five hectare holdings.

FAO TECHNICAL PAPERS

WATER REPORTS

1	Prevention of water pollution by agriculture and related activities, 1993 (E S)
2	Irrigation water delivery models, 1994 (E)
3	Water harvesting for improved agricultural production, 1994 (E)
4	Use of remote sensing techniques in irrigation and drainage, 1995 (E)
5	Irrigation management transfer, 1995 (E)
6	Methodology for water policy review and reform, 1995 (E)
7	Irrigation in Africa in figures/L'irrigation en Afrique en chiffres, 1995 (E/F)
8	Irrigation scheduling: from theory to practice, 1996 (E)
9	Irrigation in the Near East Region in figures, 1997 (E)
10	Quality control of wastewater for irrigated crop production, 1997 (E)
11	Seawater intrusion in coastal aquifers – Guidelines for study, monitoring and control, 1997 (E)
12	Modernization of irrigation schemes: past experiences and future options, 1997 (E)
13	Management of agricultural drainage water quality, 1997 (E)
14	Irrigation technology transfer in support of food security, 1997 (E)

Availability: December 1997

Ar – Arabic		Multil –	Multilingual
C – Chinese		*	Out of print
E – English		**	In preparation
F – French			
P – Portuguese			
S – Spanish			

The FAO Technical Papers are available through the authorized FAO Sales Agents or directly from Sales and Marketing Group, FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy.

A number of studies, including a recent joint mission by FAO and the International Program for Technology Research in Irrigation and Drainage, have shown that lack of access to affordable, improved and water-saving irrigation technologies, particularly by small-scale farmers, was one of the major constraints to irrigation development. The Subregional Workshop on Irrigation Technology Transfer in Support of Food Security was organized to discuss issues and opportunities for enhancement of farmers' access to affordable, improved and water-efficient irrigation technologies. The proceedings are presented in this publication, in two main parts. Part I gives the recommendations of the workshop adopted by the participants at the plenary session and the recommendations of the working groups. Part II contains the technical papers presented by resource persons and representatives of the irrigation equipment manufacture and supply sector. A key recommendation of the workshop was that governments, in collaboration with relevant international institutions, should formulate and implement national action programmes on technology transfer and adoption in support of small-scale irrigation.

ISBN 92 5-104072-9 ISSN 1020-1203

9 789251 040720

M 56 W7314E/1/12 97/1300